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ARMY PRELIMINARY EVALUATION OF THE PROTOTYPE BHC MODEL 211

HUEYTUG

Final Report

JOHN I. NAGATA
PROJECT ENGINEER

THEODORE K. WRIGHT
LTC, ARTY
US ARMY
PROJECT OFFICER

IVAR W. RUNDGREN
MAJ, TC
US ARMY
PROJECT PILOT

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MARCH 1969

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US ARMY AVIATION SYSTEMS TEST ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523

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ARMY PRELIMINARY EVALUATION
OF THE
PROTOTYPE BHC MODEL 211
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FINAL REPORT.

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104 p.

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abstract

The Army Preliminary Evaluation (APE) of the Bell Model 211 prototype helicopter (Hueytug) was conducted at the Bell Helicopter Test Facility, Arlington, Texas, Edwards AFB, California, and Bishop, California, from 19 October through 7 November 1968. Flying qualities, performance, and mission suitability were evaluated to determine aircraft capabilities to carry six thousand pound sling loads at a takeoff gross weight of 14,000 pounds. Primary emphasis was directed toward the artillery mission of displacing a 105mm Howitzer M101A1 with 10 rounds of ammunition and 3 cannoneers. The helicopter had eight deficiencies which require mandatory corrections. Two of these are major design deficiencies that may require extensive engineering redesign. They are the directional oscillations in the 30 to 60 KIAS airspeed range, especially prevalent during heavy sling load missions; lack of sufficient directional control margin during high gross weight (14,000 pounds) and high density altitude (above 4000 feet) conditions. The remaining six deficiencies are ineffective force trim feature at high airspeeds, excessive forward position of longitudinal control at high airspeeds, poor static engine droop compensation, tail rotor drive train torque limitations, lack of an engine power torque limiter and lack of a standby generator for IFR flight. There are seven shortcomings the corrections of which are desirable and should be accomplished as soon as possible. The prototype model 211 could marginally perform the 14,000 pound gross weight mission at sea level. At 4000 feet density altitude the marginal tail rotor control and transmission and drive train torque limitations prevented the helicopter from satisfactorily accomplishing the mission. Correction of the deficiencies discovered during this APE coupled with the 200 horsepower increase in drive train torque limits of the design proposal should result in a superior performing helicopter. Correction of the deficiencies should be accomplished prior to a production contract.

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INTRODUCTION

BACKGROUND

1. In 1966 the Bell Helicopter Company (BHC) commenced the development of an artillery-prime mover version of the UH-1 helicopter Concurrently, BHC also began developing the dynamic components for a 2000 shaft horsepower (shp) drive system. In early 1968, a converted model UH-1C with increased horsepower, larger rotor blades and additional modifications was first flown and introduced as the BHC Model 211 (Hueytug). The prototype Hueytug was designed to transport sling loads weighing up to 6000 pounds at a design takeoff gross weight of 14,000 pounds. The Hueytug is also designed for battlefield recovery of downed aircraft, command and control, medical evacuation and resupply missions. The US Army Aviation Systems Test Activity was directed by the US Army Aviation Systems Command (ref 1, app I) to perform an Army Preliminary Evaluation (APE) on the prototype BHC Model 211 (Hueytug).

TEST OBJECTIVES

2. The objectives of this test were to evaluate the helicopter performance, stability and control characteristics within the established flight envelope, and to determine mission suitability. This evaluation was conducted with internal and external loadings, with particular emphasis on known stability and control deficiencies found in the UH-1B/C (ref 3, app I).

DESCRIPTION

3. The prototype Model 211 helicopter is a modification of the UH-1B/C series helicopter and is designed for the external transportation of heavy loads. Modifications incorporated in the basic airframe are as follows:

a. T55-L-7B turboshaft engine with a takeoff power rating of 2650 shp at sea level standard day conditions.

b. Fifty foot diameter two bladed main rotor with a 27 inch chord.

c. Rotor mast extended 12 inches.

d. Eighteen hundred shp dynamic drive system.

e. Tail boom structurally reinforced and extended 45.25 inches.

f. Tail rotor diameter of 9 feet, 8 inches.

g. Increased structural rigidity of the fuselage.

h. Three axis stability and control augmentation system (SCAS).

4. The design proposal of the Model 211 includes the following modifications not present in the prototype:

a. T55-L-7C Lycoming turbo shaft engine with a takeoff rating of 2850 shp at sea level standard day conditions.

b. Two thousand shp dynamic drive system.

c. Tractor tail rotor.

d. Main rotor and tail rotor blades incorporating two double sweep back blades (outboard of 80% main rotor span).

SCOPE OF TEST

5. The helicopter was evaluated as a heavy lift vehicle (14,000 pounds design gross weight) with primary emphasis on the artillery mission of displacing a 105 mm M101A1 howitzer, 10 rounds of ammunition, and a crew of three plus pilot and copilot within a 50 nautical mile (NM) radius.

6. Flight restrictions and operating limitations issued by USAAVSCOM, St. Louis, Missouri are presented in appendix II. The test conditions are presented in appendix III.

7. This test encompassed three weeks which includes ferry time and aircraft preparation. Twenty-two test flights were conducted for a total of 25.3 test hours. In addition, 15.0 hours were flown ferrying the aircraft from Arlington, Texas, to a high altitude test site at Bishop, California.

METHOD OF TEST

8. Performance and stability and control test techniques as outlined in reference 2, appendix I, were adhered to in obtaining the pertinent helicopter characteristics. Deviations to the above are clarified in paragraphs 9 and 10.

9. Slow speed data were obtained by stabilizing the helicopter in sideward, rearward, or forward flight, with the aid of a pace vehicle with calibrated anemometer. Control position data and anemometer readings were recorded.

10. Static longitudinal stability (collective fixed) was evaluated in climbing flight by performing constant power setting climbs through a density altitude of 5000 feet at selected airspeeds above and below the best climb speed (62 KCAS).

CHRONOLOGY

11. The chronology of this APE is as follows:

Test directive received	11 September 1968
Test plan submitted	5 October 1968
Test team arrived at contractor's facility	13 October 1968
Flight test commenced	19 October 1968
Flight test completed	7 November 1968
Test helicopter returned to contractor	7 November 1968
Preliminary report submitted	12 December 1968
Final report	March 1969

RESULTS AND DISCUSSION

GENERAL

12. The prototype test helicopter was evaluated within the proposed flight envelope for limited performance and stability and control characteristics. Problem areas specified in the UH-1B/C test report were carefully compared with the flight characteristics of the Hueytug. There were no contractor or military specification guarantee requirements. Power available data were derived from Lycoming engine charts for the proposed T55-L-7C engine and for a 2000 shp dynamic drive train. The pilot's rating scale (app VI) was used for stability and control evaluation. Test instrumentation used during the conduct of the test are presented in appendix V. Power available and fuel flow data for the Lycoming T55-L-7C engine are presented in figures 1 and 2, appendix IV. This data were furnished by Bell Helicopter Company and is based upon the design proposal installation with the test inlet losses of figure 22, appendix IV, applied, except that inlet particle separator screens were not installed. Power required data were determined by summing the power extracted from the accessory gearbox (C_P = 2x10^{-6}) to the calculated engine power (C_P) and dividing this sum by the speed decreaser shaft efficiency (0.988). This correction was required because of the location of the pickup for the engine torquemeter. All stability and control testing was performed with the SCAS operating unless otherwise specified. Control motion data are presented in percent of control travel on stability and control plots. Amount of control movement with percent travel data are presented in appendix VII. Control forces are unchanged from a UH-1P/C helicopter.

HOVER PERFORMANCE

13. Hover performance tests were conducted at density altitudes ranging from 2110 feet to 10,540 feet. Tests were conducted at skid heights of 7 feet in ground effect (IGE) and 100 feet out of ground effect (OGE). The tethered hover method of test was used with an attached calibrated load cell to determine the load at various power and rotor rpm settings. Quantitative data are presented in figure 3, appendix IV, and the hovering summary for OGE capability is presented in figure 4. The summary plot was derived from the T55-L-7C engine power available charts and a transmission limit of 2000 shp. With the above criteria, the maximum altitude that the helicopter can hover OGE on a standard day at 14,000 pounds gross weight is slightly greater than 10,000 feet. On a 35 degree centigrade hot day, the maximum OGE hover altitude is

00 feet. During a tethered hover test at a density altitude of 10,540 feet, rotor rpm 280, full left directional pedal was required to maintain direction at 59 percent engine torque (1700 shp). Hover performance is satisfactory providing tail rotor control power is increased to allow usage of the full 2000 shp of the design proposal.

LEVEL FLIGHT PERFORMANCE

General

1[illegible]. Level flight performance tests were conducted to determine the power required as a function of airspeed. Various gross weights, altitudes and sling load configurations were used to achieve a wide range of thrust coefficients (C_T). Quantitative data are presented in figures 5 through 15, appendix IV, and summarized in figures 16 and 17. Combinations of cargo doors and cargo mirror on or off were flown to determine the equivalent flat plate area (F_e) penalty. Figures 10 and 11, show that with the cargo mirror on and cargo doors open a 5.5 square feet increase of F_e or 9.5 percent increase in power required occurred at 120 knots true airspeed (KTAS) as opposed to the doors closed, mirror off configuration. With the cargo doors open (see fig 12 and 13), the F_e was increased 2.0 square feet resulting in a 4.2 percent increase in power required at 120 KTAS. The cargo mirror by itself created 3.5 square feet of F_e. A 105 mm howitzer M101A1 with ten rounds of ammunition was used as a sling load in one level flight performance test. Figure 15 shows 27 percent increase in power required at the limit airspeed of 80 KTAS. Another test used a conex container as a sling load (fig 14). This conex container required an increase of 21.8 percent power at 60 KTAS.

TABLE 1. Next Page

Table 1. Equivalent Flat Plate Summary.

Configuration	Incremental Equivalent Flat Plate, ΔF_e
Cargo doors closed	- 2.0 ft^2
Cargo mirror off	- 3.5 ft^2
Cargo doors closed and cargo mirror off	- 5.5 ft^2
105 howitzer and 10 pounds of ammunition	54 ft^2
conex container	94 ft^2

The ΔF_e is based on a comparison of the helicopter with cargo doors open and cargo mirror on configuration. The ΔF_e of the sling loads is based on extrapolated data based on the above configuration.

Range Performance

15. Range performance (fig 18, app IV) was calculated from the level flight performance data for sea level standard day conditions with cargo doors open and cargo mirror on. Radius of action for the artillery mission of displacing the 105 mm M101A1 howitzer at 80 KTAS with 10 rounds of ammunition and three cannoneers, then returning empty to home base at 140 KTAS with 10 percent reserve fuel is 54 NM and was computed as follows:

Takeoff Condition	Pounds
a. Empty weight	5791
Crew (2)	400
105 mm howitzer plus 10 rounds of ammunition	5840
Cannoneers (3)	600
Fuel	1369
Takeoff gross weight	14000 pounds

		Pounds
b.	Total fuel	1369
	Ten percent reserve fuel	137
	Warm up, hook up, climb fuel	82
	Useable fuel	1150 pounds
c.	Combat radius	54 NM

The one way range is 97 NM for the artillery displacement mission at 80 KTAS and a takeoff gross weight of 14,000 pounds using the same fuel requirements as above. The fuel flow was based on the fuel flow of the T55-L-7C engine, figure 2.

Endurance

a. Endurance values for cargo doors open, cargo mirror on for three gross weights and two configurations are presented in table 2. The fuel flow criteria were based on the T55-L-7C engine, figure 2.

Table 2. Endurance.

Sea Level Standard Day 10% Reserve Fuel 82 lb Warm-up and Climb Fuel				
Gross Weight (lb)	Configuration	Useable Fuel (lb)	Endurance Airspeed (KTAS)	Endurance Time (hours)
* 8,000	doors open mirror on no sling load	1334	59	2.2
** 10,500	same as above	1334	60	2.0
14,000	doors open mirror on sling load 105 mm howitzer 10 rounds ammunition piggyback	1150	60	1.4

* Gross weight based on full fuel, pilot and copilot, and mission essential equipment.

** Gross weight is the maximum allowable for internal loading.

AUTOROTATION

17. Autorotation tests were conducted at two gross weights (8000 and 10,550 pounds) at an average density altitude of 3000 feet. The quantitative data are presented in figure 19, appendix IV. The airspeed for minimum rate of descent was 62 KCAS which gave a rate of descent of 1662 fpm. The airspeed for maximum glide distance (78 KCAS) produced a rate of descent of 1825 fpm. For every 1000 feet of descent, 4300 feet of horizontal distance is traversed. There were no unusual aircraft characteristics observed during these tests. At an airspeed of 62 KCAS, tests were conducted at various rotor rpms. Figure 20 shows that the low rotor rpm (282.5) produced a rate of descent of 1482 fpm, while the high rotor rpm (311.0) had a corresponding rate of descent of 1960 fpm. Gross weight differences did not alter the minimum rate of descent during these tests. Future tests should be conducted at heavier gross weights using external sling loads to determine how the rate of descent varies with gross weight.

AIRSPEED CALIBRATION

18. The pace method (UH-1C) was used for airspeed calibration. This was performed by comparing the sensitive calibrated boom airspeed systems installed on both the test and pace helicopters. The airspeed calibration data are presented in figure 21, appendix IV. The standard aircraft airspeed and altimeter were not calibrated.

STABILITY AND CONTROL

Dynamic Lateral-Directional Stability

19. Qualitative results of the dynamic lateral-directional stability characteristics were obtained by releasing from steady heading sideslips, directional control "doublets," and flight evaluation during gusty atmospheric conditions. The helicopter exhibited a lateral-directional oscillation which was primarily present in the 30 to 60 KIAS band. The motion was essentially a yaw oscillation which was easily excited during gusty conditions. During a sling load test sequence the helicopter transmitted the yaw oscillation to the piggyback load (10 rounds of ammunition slung below a 105 mm howitzer). The ensuing lateral oscillation (neutrally damped) was severe enough to cause side forces resulting in full ball deflection of the turn and slip indicator. Airspeed and power changes were required to stop the oscillation. The present directional axis SCAS capability is inadequate to cope with the subject lateral-directional oscillation. The lateral-directional characteristics of the helicopter are adequate to

perform the intended mission. However, as presently configured, this characteristic may cause some pilots to jettison their sling loads prematurely. The lateral-directional oscillation in the 30 to 60 KIAS band is a deficiency the correction of which is mandatory (PRS U7). Dynamic short period tests revealed an essentially deadbeat oscillation in both the lateral and directional axes (PRS-A3).

Static Lateral-Directional Stability

20. The static lateral-directional stability tests were conducted under the configurations and conditions listed in appendix III, and the test results are presented in figures 23 through 31, appendix IV. The test helicopter exhibited positive static lateral-directional stability, that is, right pedal for left sideslip and vice versa. The neutral to slightly positive lateral cyclic gradient is indicative of limited effective positive dihedral; however, this characteristic presented no problem to the pilot. The gradient of directional control position with sideslip angle is strongly positive and indicates good apparent directional stability characteristics. Steady heading sideslips to the left at 100 KCAS were restricted to 20 degrees due to contacting the right directional limit. The linear variation of bank angle with sideslip angle is advantageous and reveals a linear side force characteristic. The longitudinal control gradient reveals a significant nose down-moment during left sideslip and a slight nose up-moment during right sideslip. At higher airspeeds the pitching-moment characteristic becomes more pronounced. In left sideslip at 100 KCAS and above, the nose down pitching-moment combined with the neutral lateral cyclic gradient resulted in a cyclic control position which was awkward for the pilot to control. During normal operational useage this condition should not be encountered; therefore, this characteristic presents no problem to the pilot. Static lateral-directional stability is suitable for operational use (PRS A3).

Static Longitudinal Stability

21. Static longitudinal, collective-fixed stability was evaluated in climbing flight during constant power (1300 shp) climbs through a density altitude of 5000 feet at various airspeeds around the best climb speed of 62 KCAS. Static longitudinal stability data are presented in figure 32, appendix IV. The static longitudinal gradient is slightly positive. This shallow longitudinal gradient coupled with nose up-pitch, which occurred when high power settings were applied, made stabilizing on a particular climb airspeed extremely difficult. Pitch attitude was the best pilot cue to desired airspeed. However, once stabilized in a climb it was not difficult to maintain the desired airspeed (PRS A3).

Longitudinal Control Motion

22. The variation of longitudinal control motion with trim airspeed in level flight with a mid cg and various gross weights is presented in figures 33 through 37, appendix IV. The longitudinal control position gradient is neutral to slightly positive at airspeeds from 30 to 60 KCAS. At airspeeds above 60 KCAS the gradient becomes more positive. The neutral to slightly positive gradient at the slower airspeeds effectively eliminates longitudinal control position as a cue to airspeed desired and forces the pilot to rely on pitch attitude as the only reliable reference with which to select a desired airspeed. These airspeeds are on the backside of the power required curve where no speed stability exists and complicates the pilot's task of stabilizing on a particular airspeed below 60 KCAS. Even though it is difficult to stabilize on an exact airspeed within this airspeed band, the aircraft can be flown through this band with little pilot effort, and does not adversely affect mission accomplishment. At airspeeds above 60 KCAS where a positive stick gradient exists and speed stability is present, stick position is useable as a cue to airspeed desired (PRS A3).

Dynamic Longitudinal Stability

23. Dynamic longitudinal stability tests were conducted under the conditions listed in appendix III. The longitudinal SCAS effectively eliminates the long period oscillation. With longitudinal SCAS "OFF" the long period oscillation is not easily excited; therefore, it is not a problem to aircraft control. Once forced into a long period oscillation by trimming in level flight and then slowing the airspeed 15 KIAS and returning the controls to trim, the helicopter exhibited a divergent phugoid oscillation. Dynamic short period tests revealed an essentially deadbeat oscillation in the longitudinal axis (PRS A3).

CONTROL RESPONSE

Longitudinal Control Response

24. Longitudinal control response tests with SCAS "on" and SCAS "off" were conducted during OGE hover and stabilized forward flight using step inputs from approximately 1/2 to 1 inch. Tests were conducted under the conditions specified in appendix III. Longitudinal control response data are presented in figures 38 through 42, appendix IV. After initial longitudinal displacement the resulting angular acceleration was in the proper direction within 0.2 seconds. During SCAS "on" testing, pitch damping was satisfactory in all conditions tested. During SCAS "off" testing pitch damping was minimal, resulting in pitch rates which built rapidly but

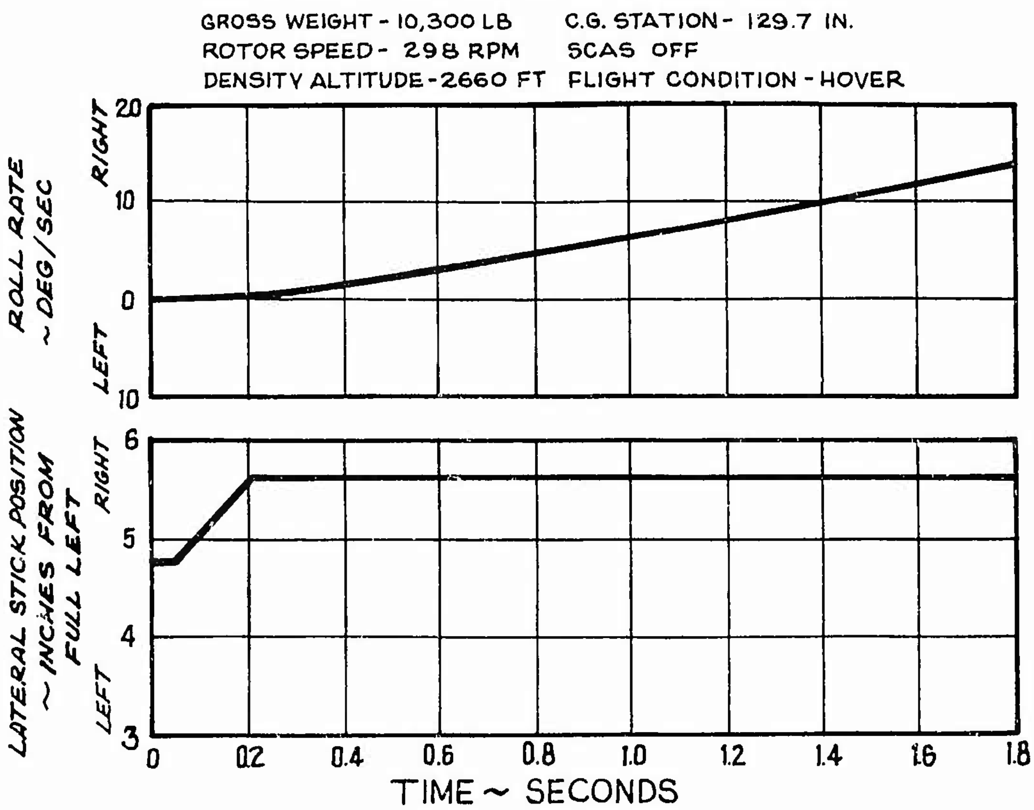
were not objectionable. The longitudinal control response and control power are satisfactory for operational use (PRS A3).

Lateral Control Response

25. Lateral control response characteristics were evaluated under the test conditions outlined in appendix III. The data were obtained in OGE hover and stabilized forward flight using step inputs of approximately 1/2 to 1 inch. The data are presented in figures 43 through 47, appendix IV. During SCAS "on" testing lateral step inputs produced satisfactory roll rates in both directions; roll rates to the right were slightly greater than roll rates to the left. With SCAS "off," roll rates built rapidly at an ever increasing rate as shown on figure A. Lateral control response and control power (SCAS "off" and "on") are satisfactory for operational use (PRS A3).

FIGURE A. TIME HISTORY OF RIGHT LATERAL INPUT

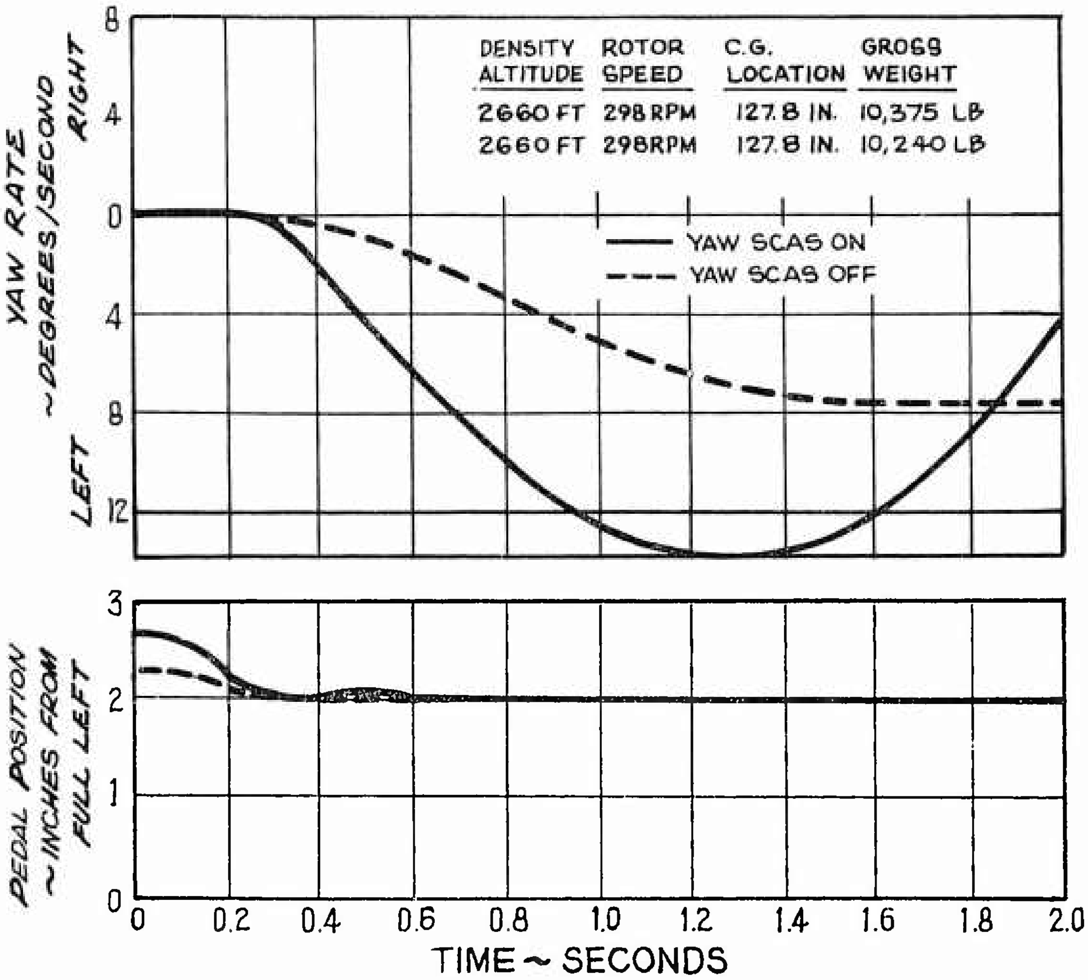
MODEL 211 S/N N6256 N · HUEY TUG



Directional Control Response

26. Directional control response characteristics were evaluated under the conditions outlined in appendix III. The data were obtained in OGE hover and stabilized, forward flight using step inputs of approximately 1/2 to 1 inch. The data are presented in figures 48 through 53, appendix IV. At a hover, step inputs in the directional axis produced acceptable yaw rates to the right with angular acceleration in the proper direction within 0.2 seconds after control displacement. Step inputs to the left, with SCAS "on," were characterized by acceptable initial yaw rates which quickly approached zero rate as shown in figure B.

FIGURE B TIME HISTORY OF LEFT DIRECTIONAL INPUT
MODEL 211 S/N N6256N



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The inability to generate a constant yaw rate to the left while at a hover is a shortcoming, the correct of which is desirable (PRS A5).

SIDEWARD AND REARWARD FLIGHT

27. Sideward and rearward flight was evaluated under the conditions outlined in appendix III. The variation of directional and lateral control positions versus airspeeds in sideward flight is presented in figures 54 through 58, appendix IV. The gradient of lateral cyclic control with airspeed was slightly positive throughout the airspeed band tested. The directional control gradient was positive. From zero to 15 KIAS it was difficult to stabilize at a constant airspeed and constant heading because the motion of the helicopter was characterized by random yaw oscillations which required large and rapid movements of the directional control. During sideward and rearward flight at airspeeds above 15 KIAS the helicopter was easily controlled. These tests were conducted during calm nonturbulent atmospheric conditions. During a sling load test at a gross weight of 13,700 pounds and at an approximate density altitude of 4000 feet, left sideward flight at airspeeds greater than 10 KIAS could not be achieved due to tail rotor torque limitations. The control margin at this condition was less than 10 percent. The limited control margin at these conditions is a deficiency, the correction of which is mandatory (PRS U7).

28. Rearward flight test results are presented in figures 59 through 62, appendix IV. While at a maximum internal loading condition the maximum rearward velocity achieved was 20 KTAS. The longitudinal control position gradient was positive from hover to 15 KTAS rearward, and then changed to a neutral gradient from 15 to 20 KTAS rearward. At 20 KTAS the margin of longitudinal control remaining was 40 percent. The rearward flight characteristics are satisfactory for operational use (PRS A3).

CONTROL MARGIN

29. During stabilized level flight at V_{NE}, while at a mid cg and sea level condition, there remained 6 percent of forward longitudinal control. This insufficient longitudinal control margin is a shortcoming, the correction of which is desirable (PRS A6). Additionally, the pilot was required to stretch uncomfortably forward in order to achieve the required forward longitudinal control for V_{NE} flight. The force-trim feature at airspeeds greater than 125 KIAS was ineffective. At airspeeds greater than 125 KIAS the pilot was required to physically overcome longitudinal trim spring pressure to obtain the desired incremental airspeed change. The

continuous force applied by the pilot at V_{NE} flight becomes excessively tiring. An ineffective force trim system at high airspeeds and the excessive forward control travel at high airspeeds are deficiencies, the corrections of which are mandatory (PRS U7).

SIMULATED POWER FAILURES

30. Simulated power failures with a sling load of 4500 pounds were conducted from stabilized, climbing and level flight at a gross weight of 13,000 pounds with a density altitude of 5000 feet. Table 2 summarizes the test results. Simulated power failures resulted in a minimum of pitch and roll attitude changes. For the airspeeds investigated, yaw-attitude change was observed 0.2 to 0.5 seconds after initiation of the simulated power failure. The initial and immediate yaw attitude change of approximately 5 degrees is an acceptable cue in alerting the pilot to an engine failure situation. Simulated power failures at higher torque values resulted in a more rapid decay of rotor speed. The rotor speed time decay interval was measured from 296 rpm to 280 rpm. The simulated power failure characteristics of the test helicopter are satisfactory for operational use (PRS A3). Additional testing at a light gross weight configuration and high power climb condition is recommended to further define flight envelope restrictions.

Table 2. Simulated Power Failure Characteristics.

Flight Conditions	Airspeed (KCAS)	Torque (%)	Rotor Decay Time (sec)
Level	60	34	2.25
Level	80	40	2.25
Climb	80	44	2.0
Climb	80	48	1.80
Climb	80	52	1.70

SLING LOAD OPERATIONS

31. During the conduct of this test the four types of sling loads carried were as follows:

a. Piggyback - 105 mm howitzer M101A1 with 10 rounds of ammunition (6000 pounds).

b. Conex container with 2400 pounds of ballast for a total of 3900 pounds.

c. Simulated military vehicle - automobile (1950 pounds).

d. Lead weights of varying dimensions (from 1000 to 4500 pounds).

32. A lateral directional oscillation was experienced during a piggyback sling load test as explained in paragraph 19.

33. Both a directional and a longitudinal oscillation were experienced while carrying the conex container and simulated military vehicle. The maximum useable velocity attained with the vehicle was 90 KIAS while 80 KIAS was the maximum useable for the conex container in smooth air. In light to moderate turbulence with SCAS "on," pitch oscillations transmitted by the conex sling load resulted in increased pilot effort and limited the maximum useable speed to 50 KIAS (PRS A5). Dense objects such as lead weights presented no sling load problems. Because of the increased capability of this aircraft to sling load various items, further tests should be conducted to determine the optimum cable types, lengths, and rigging conditions for these items to reduce oscillations and possibly increase airspeed limits.

STABILITY AND CONTROL AUGMENTATION SYSTEM

34. The SCAS, as incorporated in the prototype test helicopter, reduced pilot workload and was especially helpful during heavy sling load operations. The entire mission profile can be conducted with the SCAS inoperative; however, pilot effort approaches a maximum because of the high roll sensitivity and low roll-damping characteristic. Pilot induced oscillations (PIO) are very prevalent with SCAS "off." Commitments involving prolonged operations require a properly functioning roll channel (PRS A5). The pitch channel results in no significant reduction of pilot workload and is, therefore, not necessary for satisfactory operational use (PRS A3). The yaw channel as presently configured has insufficient gain to satisfactorily prevent yaw oscillations in slow speed flight (zero to 60 KIAS). This is especially noticeable during heavy gross weight, sling load operations. The yaw channel exhibits excessive gain in high speed flight (60 to 140 KIAS) which causes large yaw accelerations following gust disturbances with small yaw attitude changes. As presently configured the yaw SCAS is not useable. The yaw SCAS to provide proper gains to prevent yaw oscillations at all airspeeds and loading conditions is a shortcoming for which correction is desirable (PRS A5).

MISCELLANEOUS

Collective Creep

35. During the conduct of the test, principally during periods of high vibration levels (2/rev), the collective control tended to creep upward. At V_{NE} flight the collective control had to be locked into position by the collective friction adjustment to prevent inadvertent power changes. Correction of the collective creeping tendency is desirable for improved operational use.

Structures

36. During the APE the left-forward-engine mount failed (cracked rod end), and the elevator-bellcrank-attaching bracket (located below the engine) fatigued and cracked. Prior to the Army test, the tail boom structure itself developed cracks which were repaired and the tail boom was structurally reinforced. Recommend that the airframe area, surrounding and supporting the T-55 engine and the tail boom structure with its mountings, be investigated for structural integrity prior to future Army testing.

Vibration

37. A 2/rev vibration is prevalent throughout the airspeed envelope. This vibration is a shortcoming and is especially noticeable and bothersome at high-density altitudes and at heavy gross weight conditions. Reduction in the 2/rev vibration is desirable for improved operational use.

Power Management

38. The rpm governor control characteristics of the test helicopter were undesirable. Continuous manipulation of the rpm governor beep switch was required during engine power output changes. This characteristic required an unusual amount of pilot attention. Correction of these engine-droop characteristics is mandatory for satisfactory operational use.

Drive Train Limitations

39. Full left directional control was restricted due to tail rotor gearbox torque limits. The last 10 percent of left directional pedal travel was not useable. Correction of the tail rotor dynamic drive system to permit full and effective pedal deflection during any flight condition is mandatory.

Torque Limiter

40. Due to the large pilot workload during hover at maximum gross weight, the pilot and the copilot were unable to continuously monitor the engine torque. At this same flight condition, the power requirements approach the drive train limits on many sling load missions. To prevent inadvertent overtorque of the dynamic drive train components, installation of a torque limiter is mandatory.

Noise Level

41. The noise level at V_{NE} (140 KTAS) was excessive due primarily to vibration in the airframe (doors, etc) which made outside radio communication difficult. Correction of this shortcoming is desirable for improved operational use.

Gearbox Temperatures

42. The 42-degree tail rotor gearbox exceeded its temperature limits (166^{o}F) twice during the test program. Once during flight at V_{NE} (by 5 - 10 degrees F) with an OAT of 95 degrees F and once during high density altitude tethered hovering. The tendency of the 42-degree tail rotor gearbox to overheat is a shortcoming, the correction of which is desirable for improved operational use.

Power Source Limitations

43. The transmission mounted generator is not available. In its place a dual-source-hydraulic system has been installed. A standby generator for instrument flight rules (IFR) flight is not available. Correction of this deficiency is mandatory for an IFR flight capability.

Cargo Mirror

44. The cargo mirror was practically useless due to high airframe vibration levels during V_{NE} flight and heavy gross weight/sling load operations. The mirror was useful only during the hookup sequence. Recommend that the cargo mirror be more rigidly secured to the airframe and in conjunction with the reduction of vibration levels a more serviceable mirror should result. Recommend remote controls be installed to allow for pilot adjustment of the cargo mirror in flight in order to monitor the oscillations of the sling load.

CONCLUSIONS

GENERAL

45. Hover and level flight performance is sufficient to accomplish the intended mission; however, an increased range capability is desirable.

46. Tail rotor control power of the prototype was not sufficient to accomplish the intended mission.

47. The structural integrity of the area beneath the T55-L-7 engine (engine mounts and control-bell-crank brackets) and the tail boom and mountings should be scrutinized closely prior to a production contract.

48. Correction of the deficiencies discovered during this APE coupled with the 200 shp increase in drive-train-torque limits of the design proposal should result in a superior performing helicopter.

SPECIFIC

49. Within the scope of this test, correction of the following deficiencies is mandatory for satisfactory operational use:

a. Lateral-directional oscillations in the 30 - 60 KIAS airspeed band (para 19).

b. Lack of sufficient directional control margin during high gross weight (14,000 pounds) and high density altitude (above 4000 feet) conditions (para 27).

c. Ineffective force trim feature at airspeeds greater than 125 KIAS (para 29).

d. Excessive forward position of the longitudinal control during V_{NE} flight (para 29).

e. Poor static engine droop compensation characteristics (para 38).

f. Restrictions on the last 10 percent of left directional pedal travel (para 39).

g. Lack of a torque limiter to prevent inadvertent overtorque of the dynamic drive train components (para 40).

h. Lack of a standby generator for an IFR flight capability (para 43).

50. Correction of the following shortcomings is desirable for enhanced helicopter operational suitability and mission effectiveness:

a. Inability of the directional control to generate a constant yaw rate to the left during hover (para 26).

b. Insufficient forward longitudinal control margin remaining at V_{NE} cruise (para 29).

c. Inability of the SCAS yaw channel to provide proper gains in order to prevent yaw oscillations at all airspeeds and loading conditions (para 29).

d. Collective creeping tendency (para 35).

e. A 2/rev vibration throughout the airspeed envelope (para 37).

f. Excessive noise level at V_{NE} (para 41).

g. Tendency of the 42-degree tail rotor gearbox to overheat (para 42).

RECOMMENDATIONS

51. The deficiencies, corrections of which is mandatory, should be corrected prior to a production contract.

52. The shortcomings, correction of which is desirable, should be corrected prior to operational employment.

53. Further testing of this model helicopter should include autorotational tests conducted at heavier gross weights using an external sling load to determine rate of descent variation with gross weight (para 17).

54. Further testing of simulated power failures should be conducted at a light gross weight and high power climbs to further define flight envelope restrictions (para 30).

55. Further testing should include evaluation of various cable lengths and types, and rigging procedures for optimization of the sling load capability (para 33).

56. The airframe area surrounding and supporting the T-55 engine and the tail boom structure and its mountings should be investigated for structural integrity prior to further Army Testing (para 36).

57. That the pilot should have the capability of adjusting the cargo mirror in flight in order to monitor the oscillations of the sling load (para 44).

APPENDIX I. REFERENCES

1. Letter, AMSAV-R-(EF), Hq. US Army Aviation Materiel Command (USAAVCOM), Subject, "USAAVCOM TEST DIRECTIVE 68-46," 17 September 1968. USAAVCOM Project No. 68-46.

2. Test plan, USAAVNTA Project No. 68-46 "Army Preliminary Evaluation (Hueytug)," October 1968.

3. Report, USAAVNTA Project No. 64-28, "Engineering Flight Test of the UH-1B Helicopter Equipped with the Model 540 Rotor System Phase D," December 1966.

APPENDIX II. FLIGHT RESTRICTIONS AND OPERATING LIMITATIONS

AMSAV-R-EF   12 October 1968

SUBJECT: Safety of Flight Release for APE of BHC Model 211

Commanding Officer
US Army Aviation Test Activity
ATTN: SAVTE-P
Edwards Air Force Base, California

1. This letter constitutes a safety of flight release for an Army Preliminary Evaluation (APE) of the Bell Helicopter Company (BHC) Model 211 per USAAVNTA Test plan, "Flight Evaluation of the Bell Proposed Model 211," dated october 1968, in accordance with AVCOM Test Directive 68-46. Helicopter N6256N will be used for these tests.

2. Gross weight limitations are as follows:

a. Internal loadings are permissible up to a gross weight of 10,500 pounds, however, intentional power-off landings should not be performed above a gross weight of 10,100 pounds.

b. External loadings are permissible up to a gross weight of 14,000 pounds with a maximum sling load weight of 6,000 pounds.

3. Airspeed, altitude and sideslip limitations are specified in figures C thru F respectively. These limitations apply with the Stability Augmentation System operative or inoperative, with the cargo doors open or closed, and with or without the cargo mirror installed. The low speed operation of the helicopter in or near hovering flight (sideward and rearward flight) is limited as follows:

a. Sideward flight.

(1) Up to 10,500 pounds internal - 30 knots true airspeed

(2) Up to 14,000 pounds external - 15 knots true airspeed

b. Rearward flight.

(1) Up to 10,500 pounds external - 30 knots true airspeed.

(2) Up to 14,000 pounds external - 15 knots true airspeed.

Hovering turns in excess of 40 degrees per second should not be performed and rapid hovering turns and large rapid rudder pedal inputs should be avoided in order to preclude damage to the tail rotor drive system. Steady state or transient left pedal inputs within the left 10 percent of the total pedal travel should be avoided for the same reason.

4. The Maneuver limits are shown in figure F in terms of normal flight load factors. In addition, with an external sling load, a 30 degree bank angle shall not be exceeded. Maximum power climbs shall not be performed above an indicated airspeed of 100 KIAS regardless of altitude or gross weight.

5. The allowable center of gravity limits are as follows:

a. Internal configuration

Most Forward	Fus. Sta. 128
Most Aft	Fus. Sta. 135

b. External configuration

Most Forward	Fus. Sta. 132
Most Aft	Fus. Sta. 134

6. Rotor speed limits are as follows:

a.	Power on minimum	280 rpm
	Power on maximum	311 rpm
b.	Power off minimum	280 rpm (240 rpm transient)
	Power off maximum	327 rpm

7. The drive system limitations are as follows:

a. Main Transmission 18,000 in lb (59% torquemeter reading)

AMSAV-R-EF 12 October 1968
SUBJECT: Safety of Flight Release for APE of BHC Model 211

One Time Limit - Operation at or above a tail rotor horsepower of 300 hp is cause for the removal of the 90° level gears in the sump of the main transmission and inspection for scuffing or other damage.

b. 90° Tail Rotor Gearbox: 250 hp

Time - Power (Accumulated Fatigue Damage) - The time - power limits for the 90° tail rotor gearbox level gears are established as follows:

Accumulated Time	Tail Rotor SHP
2 min	375
20 min	325
3.3 hrs	275
10 hrs	255
Endurance Limit	250

Operation in excess of this time envelope is cause for retirement of gears. In addition, any operation within 0% to 10% of full left rudder pedal will require powers in excess of the 250 HP Endurance Limit as previously indicated in paragraph 3.

c. Oil Temperature Limits are as follows:

Main Transmission	110°C
42° Gearbox	110°C
90° Gearbox	110°C

d. Oil Pressure Limits are as follows:

Main Transmission	30 psi (min) 70 psi (max) (40-60 psi normal)

AMSAV-R-EF 12 October 1969
SUBJECT: Safety of Flight Release for APE of BHC Model 211

8. The Lycoming T55-L-7B Engine Limitations are as follows:

RPM	98% (100% N_I = 18,720 rpm)	
RPM	See Rotor Speed (100% N_{II} = 15,330 rpm)	
	59% (18,000 in/lb transmission limit)	
^oC	816^o Starting and Acceleration 735^o 30 minutes	
Oil Pressure	psig	300-635 normal 50-90 normal (90 max)
Oil Temperature	^oC	138^{o}C max

In addition, the allowable measured exhaust gas temperature during starting or accelerations shall be 816^{o}C maximum not exceeding 5 seconds and 746^{o}C for the remainder of the transient time.

9. This safety of flight release is contingent upon the maintenance of the aircraft being performed by the Bell Helicopter Company. Since helicopter N6256N is neither military qualified or FAA certified at this time, all maintenance procedures and safety inspections beyond those listed in this flight release are the responsibility of BHC. Limitations imposed in this release are in no way an indication of the ultimate capability of the Model 211 but merely interim limitations pending further test and analysis.

FOR THE COMMANDER:

4 Incl
as

CHARLES C. CRAWFORD, JR.
Chief, Flight Standards Office

FIGURE C. GROSS WEIGHT - AIRSPEED ENVELOPE
MODEL 211 S/N N6256 N

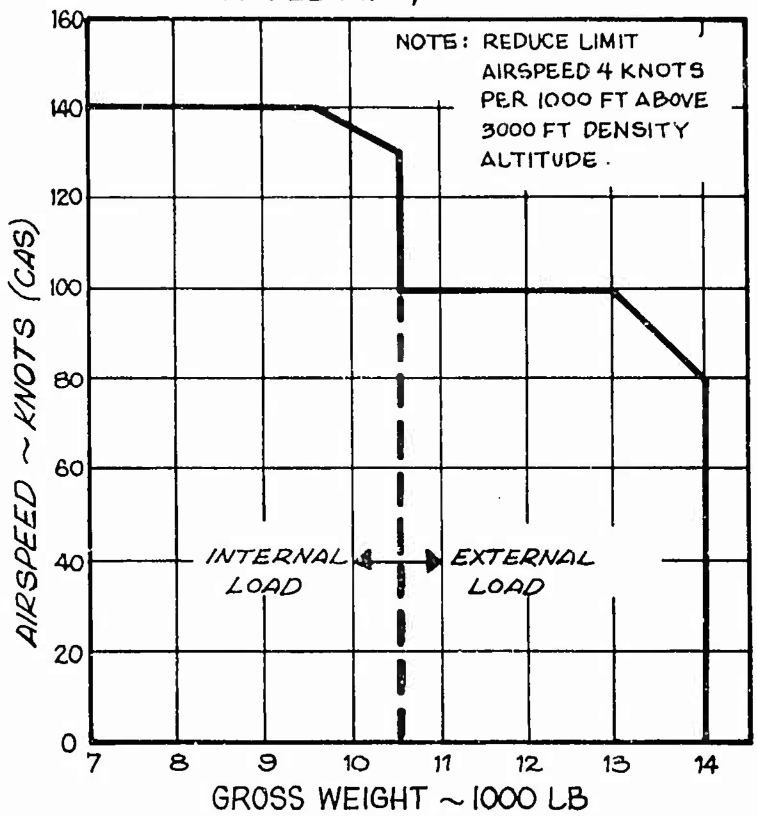
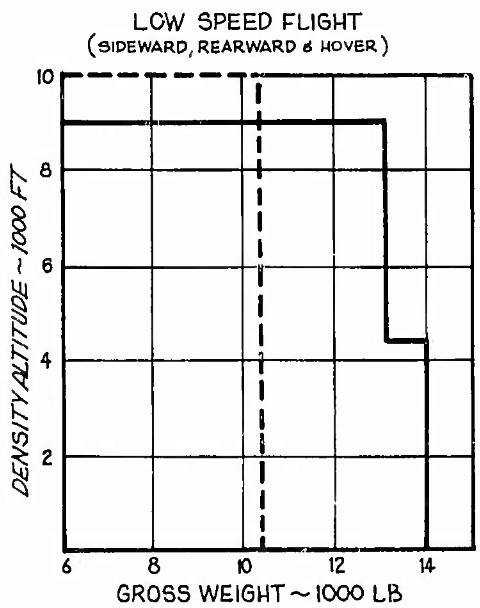


FIGURE D. GROSS WEIGHT • ALTITUDE LIMITS
MODEL 211 S/N N6256N



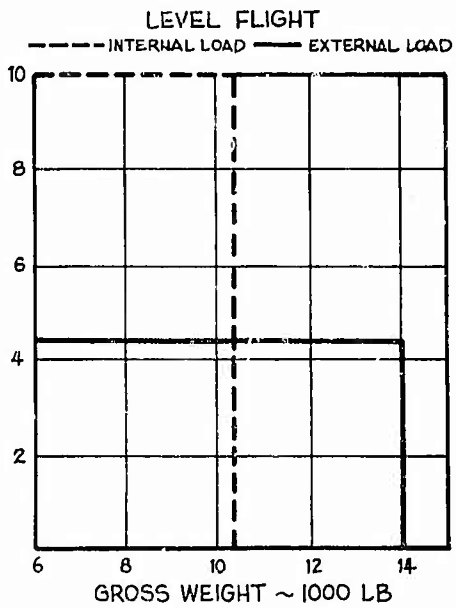


FIGURE E. SIDESLIP · AIRSPEED LIMITS
MODEL 211 S/N N6256N

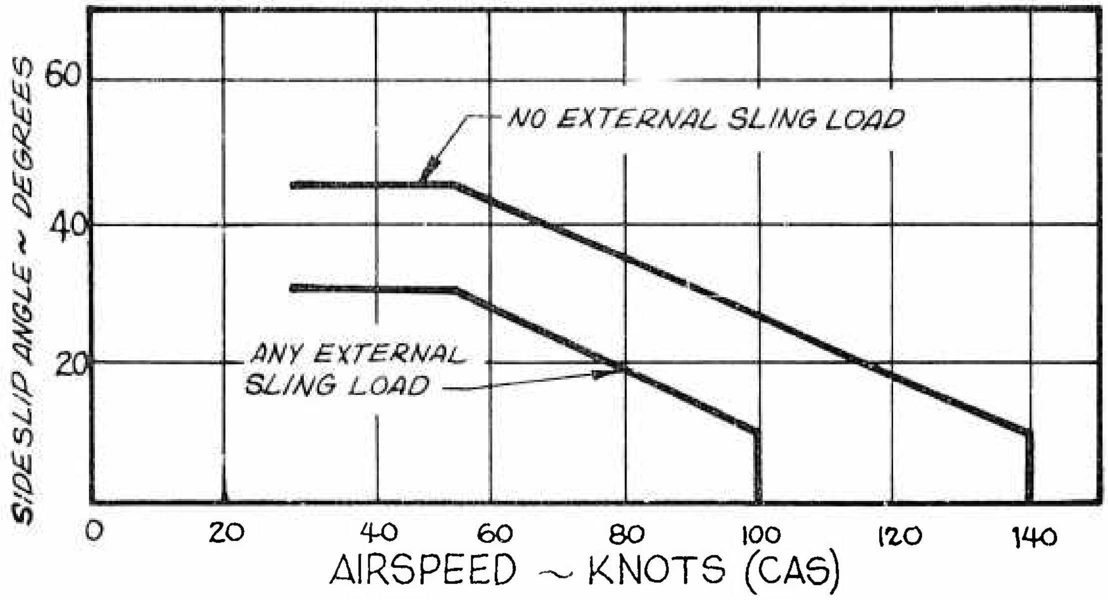
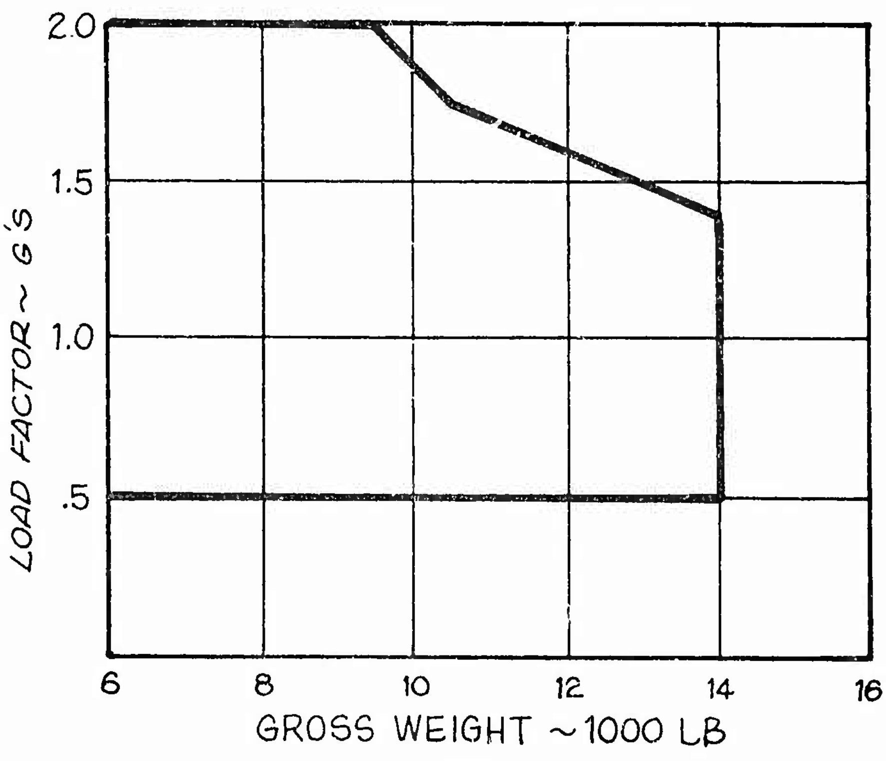


FIGURE F. ACCELERATION LIMITS
MODEL 211 S/N N6256N



APPENDIX III. PERFORMANCE TEST CONDITIONS

Test	Gross Weight lb	Cg Location in.	Density Altitude ft	Loading
Airspeed calibration	9500	132.0	3000	Clean
Level flight power required	7900	131.8	1400	Clean
"	9570	132.0	950	Clean
	9390	132.0	3050	"
	10,405	131.8	6250	"
	10,450	131.9	9900	"
	9500	132.1	2930	"
	9450	132.0	10,100	"
	7910	131.8	1500	"
	9380	132.1	3300	"
	12,740	131.8	4870	Conex container
	13,750	131.9	1710	105mm Howitzer M101A1 with 10 rounds of ammunition
Hover	Minimum G.W. to Limit parameter	132.0	2110	Tethered hover
	"		4120	"
	"		10,540	"
Autorotation	8000	132.0	5000	Clean
	10,550	132.0	3000	Clean

Test	Gross Weight lb	Cg Location in.	Density Altitude ft	Loading
Static longitudinal stability	7900 8085 10,450	131.80 133.00 131.90	1400 5000 9900	Clean Clean Clean
Dynamic longitudinal stability	8000 8200 10,550	132.00 132.00 132.00	3000 1000 3000	Clean Clean Clean
Static lateral-directional stability	8075 7835 9585	133.69 131.75 132.12	5350 4950 5015	Clean Clean Clean
Dynamic lateral-directional stability	8085	133.00	5000	Clean
Sideward flight	10,775 14,030 13,965 13,100	131.94 131.97 131.95 131.68	9855 4545 3745 1200	Sling load Sling load Sling load Sling load
Rearward flight	10,715 13,100 13,965 14,030	131.91 131.68 131.95 131.97	9855 1200 3745 4545	Sling load Sling load Sling load Sling load
Control response				
Longitudinal	7870 10,350 10,485 12,465	132.95 129.74 129.82 130.03	5155 2660 2660 2590	Clean Clean Clean Sling load
Lateral	7785 10,305 10,485 12,465	132.93 132.93 129.82 130.03	5155 5155 2660 2590	Clean Clean Clean Sling load
Directional	7725 7775 12,995 10,250 10,385 12,375	132.91 132.92 132.78 129.68 129.76 129.99	5155 6400 5480 2660 2660 2590	Clean Doors open mirror on Sling load Clean Clean Sling load

APPENDIX IV. TEST DATA

FIGURE No. 1
ENGINE SHAFT HORSEPOWER AVAILABLE
T55-L-7C ENGINE
6300 RPM

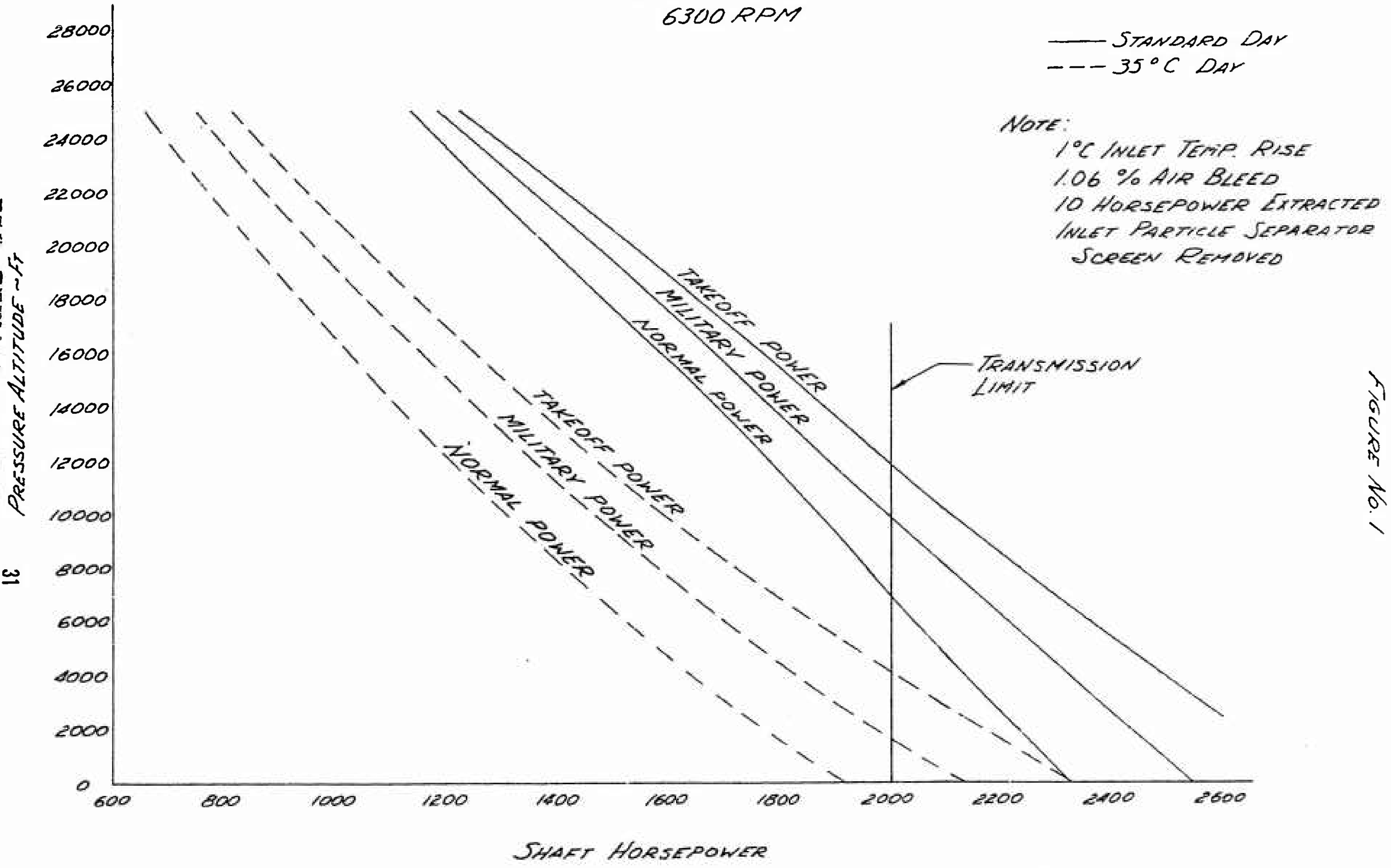


Figure No. 2

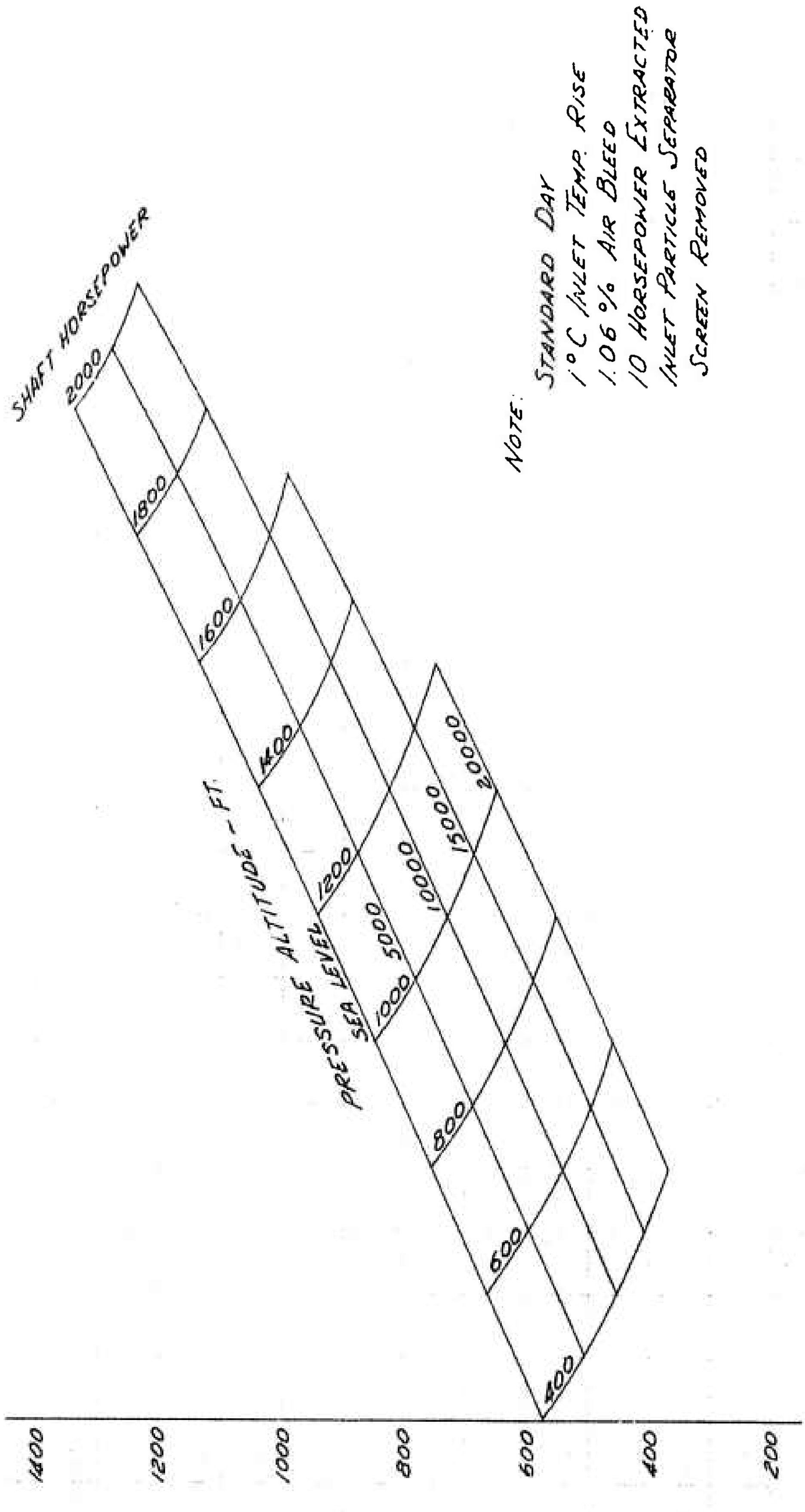


Figure No. 2
Specification Fuel Flow
T55-L-7C Engine
6300 RPM

FIGURE NO. 3
NON-DIMENSIONAL HOVERING PERFORMANCE
MODEL 211 S/N N6256N
TETHERED HOVER METHOD
WINDS LESS THAN 3 KNOTS
HUEY TUG

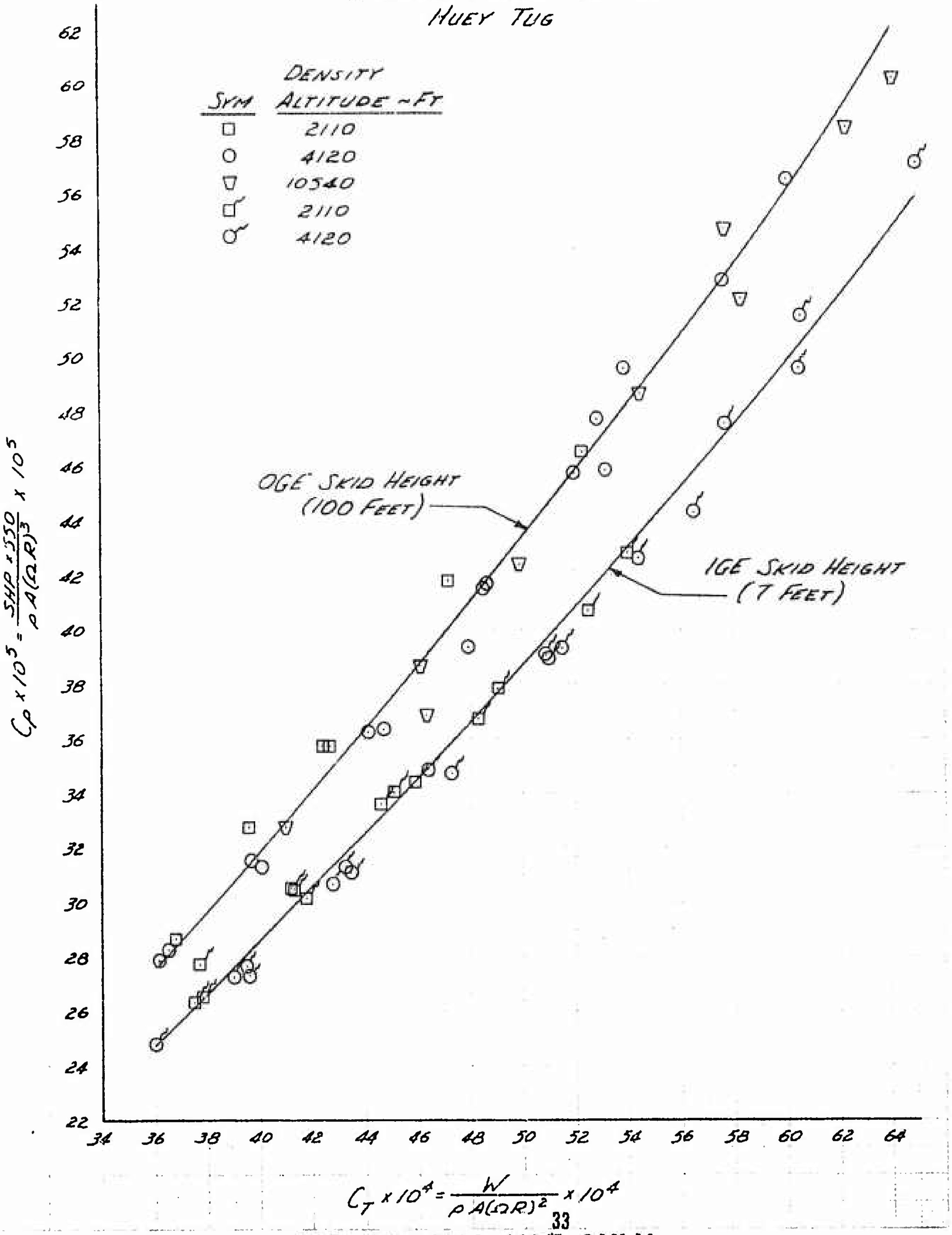


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FIGURE NO. 4
OUT OF GROUND EFFECT
HOVERING CEILING
MODEL 211 S/N N6256N
TAKEOFF POWER
HUEY TUG

NOTE:
1. SHP BASED ON T55-L-7C ENGINE MODEL SPEC. NUMBER 124-31
2. $T_{T_1} - T_A = 1°C$
3. $P_{T_1}/P_A = 1.0$
4. ROTOR SPEED = 298 RPM
5. MAXIMUM TRANSMISSION LIMIT = 2000 SHP

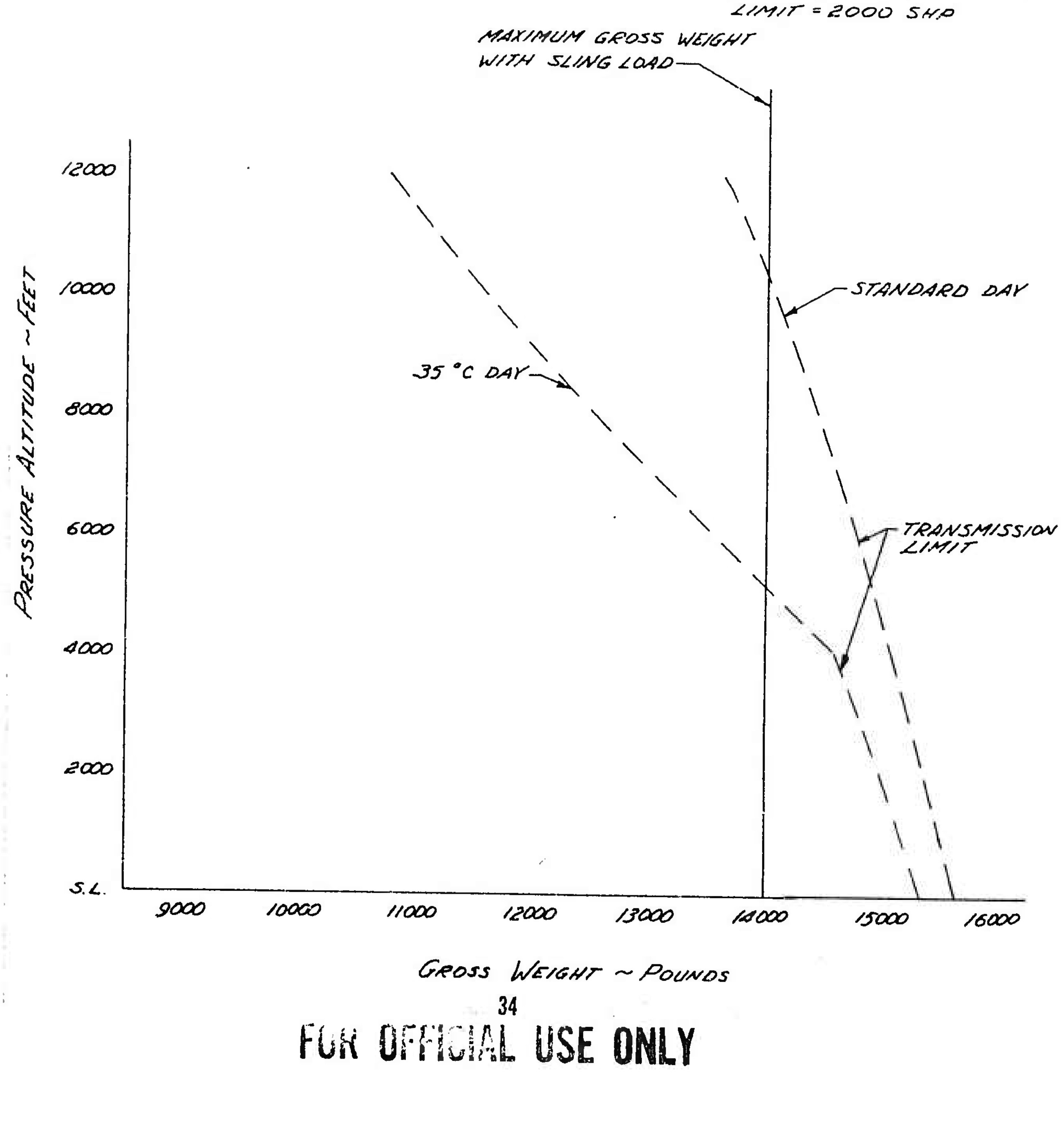

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FIGURE NO. 5
LEVEL FLIGHT PERFORMANCE
MODEL 211 S/N N6256N
HUEY TUG

GROSS WEIGHT ~ 7400 LB.
DENSITY ALTITUDE ~ 1400 FT.
ROTOR SPEED ~ 298 RPM
C.G. LOCATION ~ STATION 131.8 (MID)
C_T ~ 29.00×10^{-4}
CONFIGURATION ~ CARGO DOORS OPEN, CARGO MIRROR ON

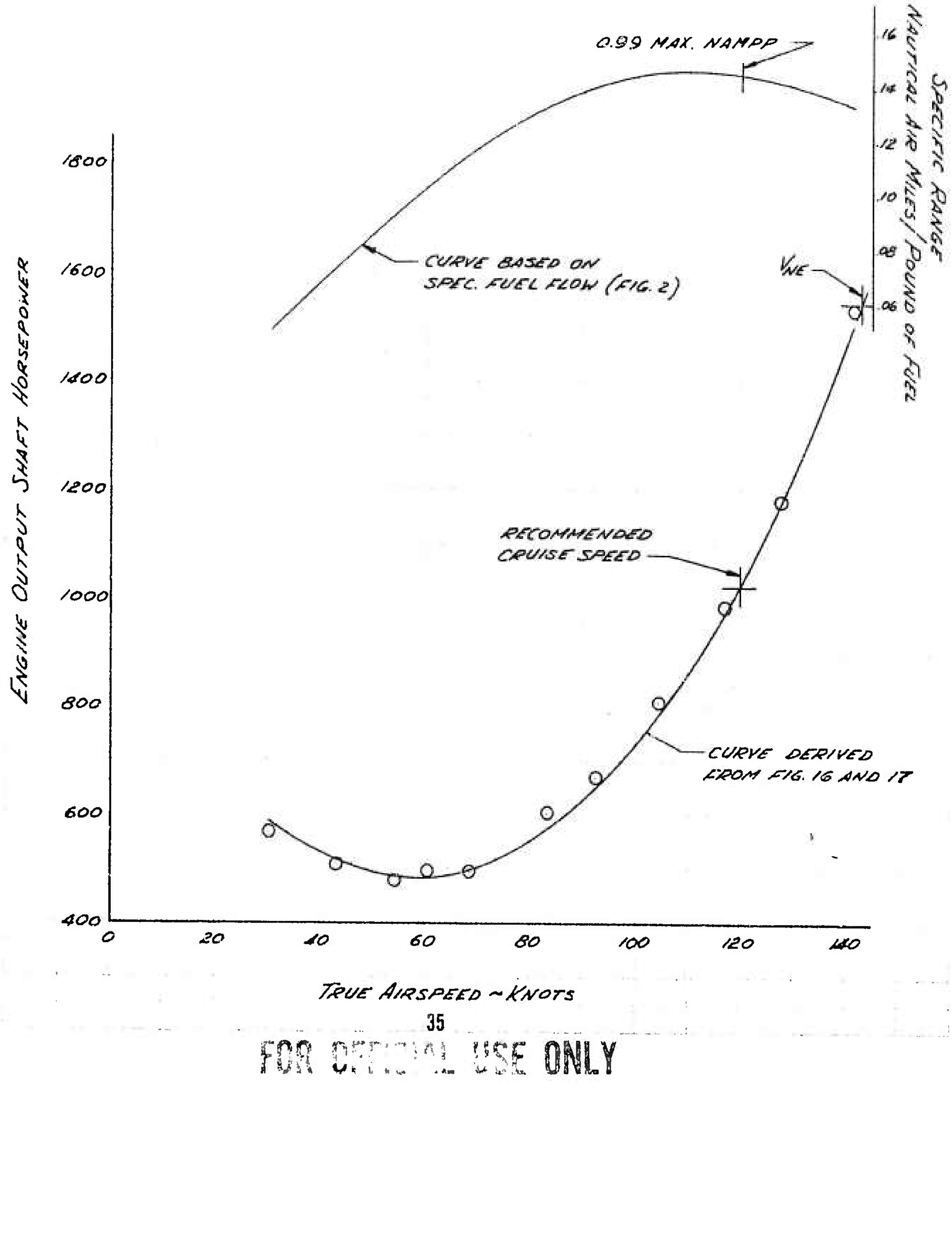

FIGURE NO 6
LEVEL FLIGHT PERFORMANCE
MODEL 211 S/N N6256N
HUEY TUG

GROSS WEIGHT ~ 9570 LB
DENSITY ALTITUDE ~ 950 FT
ROTOR SPEED ~ 298 RPM
C.G. LOCATION ~ STATION 132.0 (MID)
$C_T \sim 34.65 \times 10^{-4}$
CONFIGURATION ~ CARGO DOORS OPEN, CARGO MIRROR ON

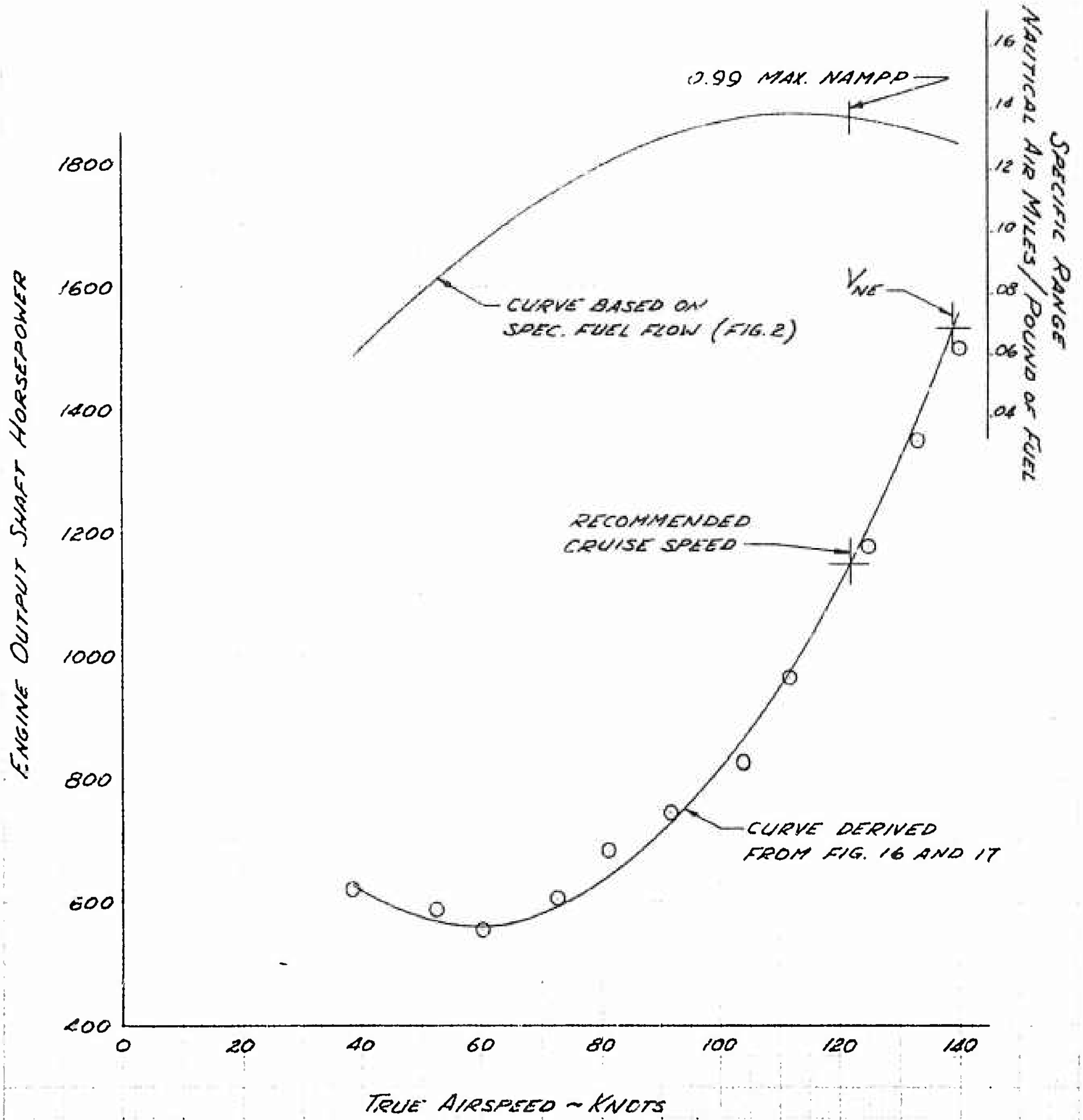

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FIGURE NO. 7
LEVEL FLIGHT PERFORMANCE
MODEL 211 S/N N6256N
HUEY TUG

GROSS WEIGHT ~ 9390 LB.
DENSITY ALTITUDE ~ 3050 FT.
ROTOR SPEED ~ 298 RPM
C.G. LOCATION ~ STATION 132.0 (MID)
$C_T \sim 36.20 \times 10^{-4}$
CONFIGURATION ~ CARGO DOORS OPEN, CARGO MIRROR ON

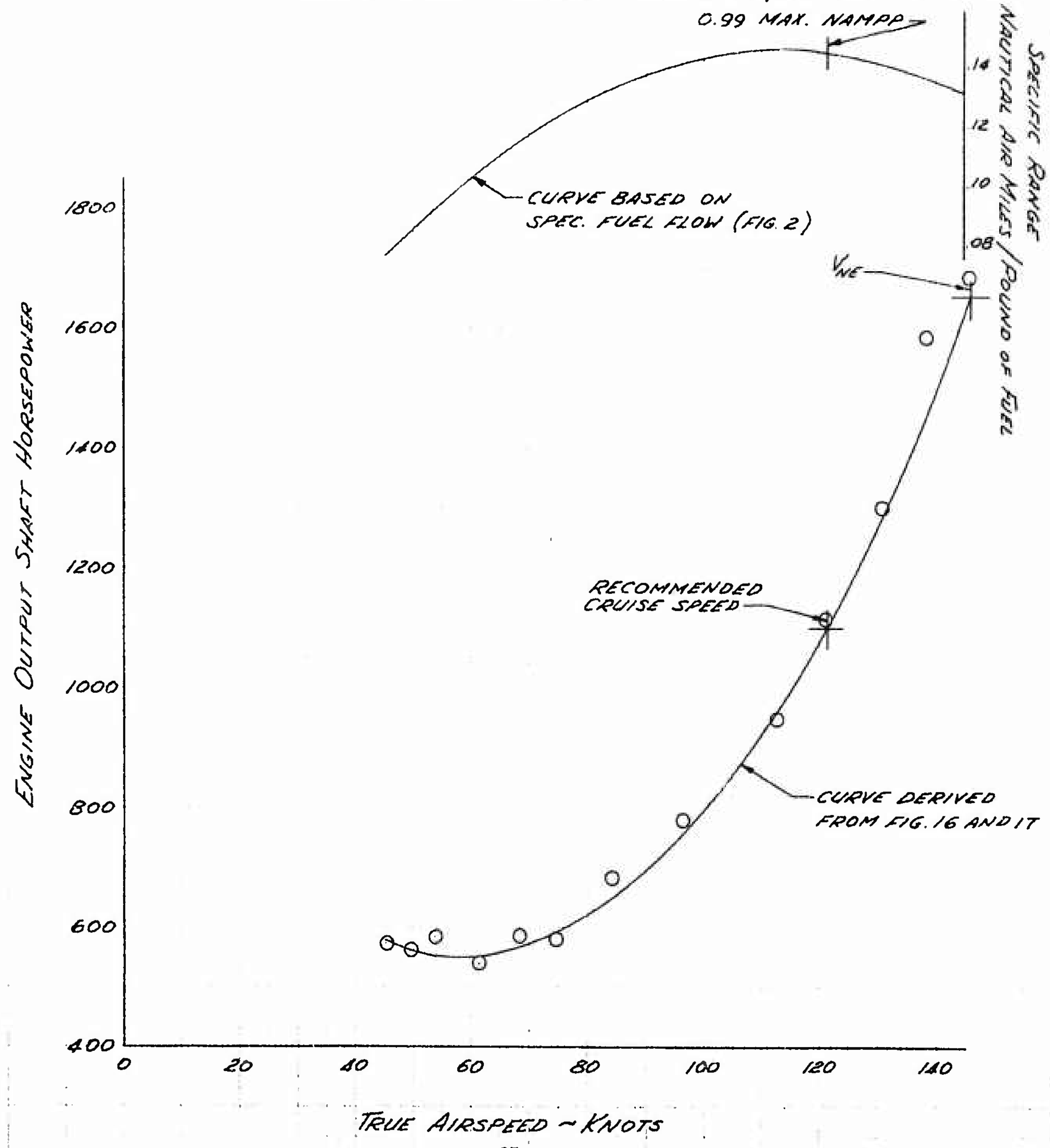

FIGURE No. 8
LEVEL FLIGHT PERFORMANCE
MODEL 211 S/N N 6256 N
HUEY TUG

GROSS WEIGHT ~ 10,405 LB.
DENSITY ALTITUDE ~ 6250 FT.
ROTOR SPEED ~ 298 RPM
C.G. LOCATION ~ STATION 131.8 (MID)
$C_T \sim 44.16 \times 10^{-4}$
CONFIGURATION ~ CARGO DOORS OPEN, CARGO MIRROR ON

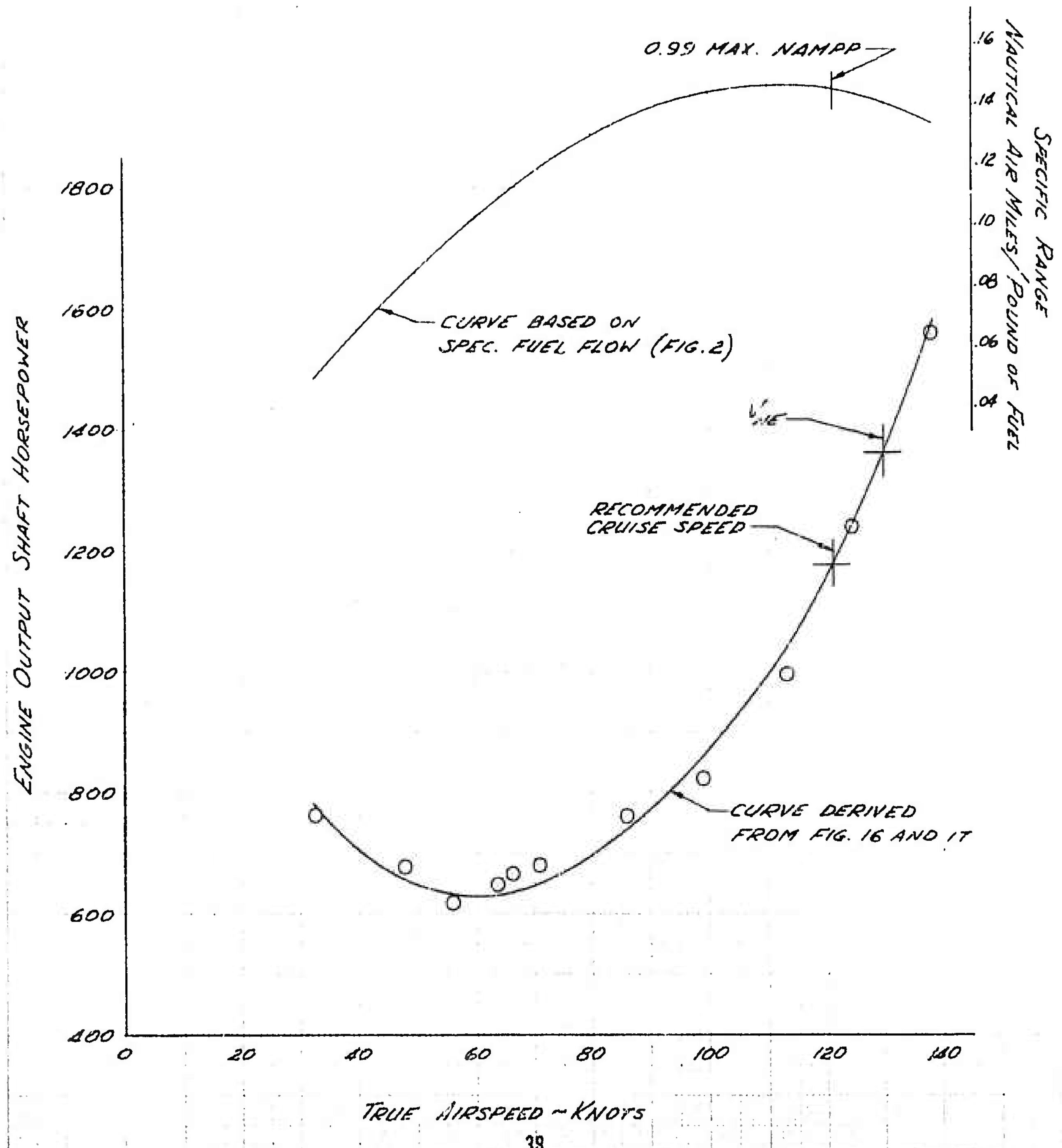

Figure No. 9
Level Flight Performance
Model 211 S/N N6256N
Huey Tug

Gross Weight ~ 10,450 LB.
Density Altitude ~ 9900 Ft.
Rotor Speed ~ 298 RPM
C.G. Location ~ Station 131.9 (Mid)
C_T ~ 49.67 x 10^{-4}
Configuration ~ Cargo Doors Open, Cargo Mirror On

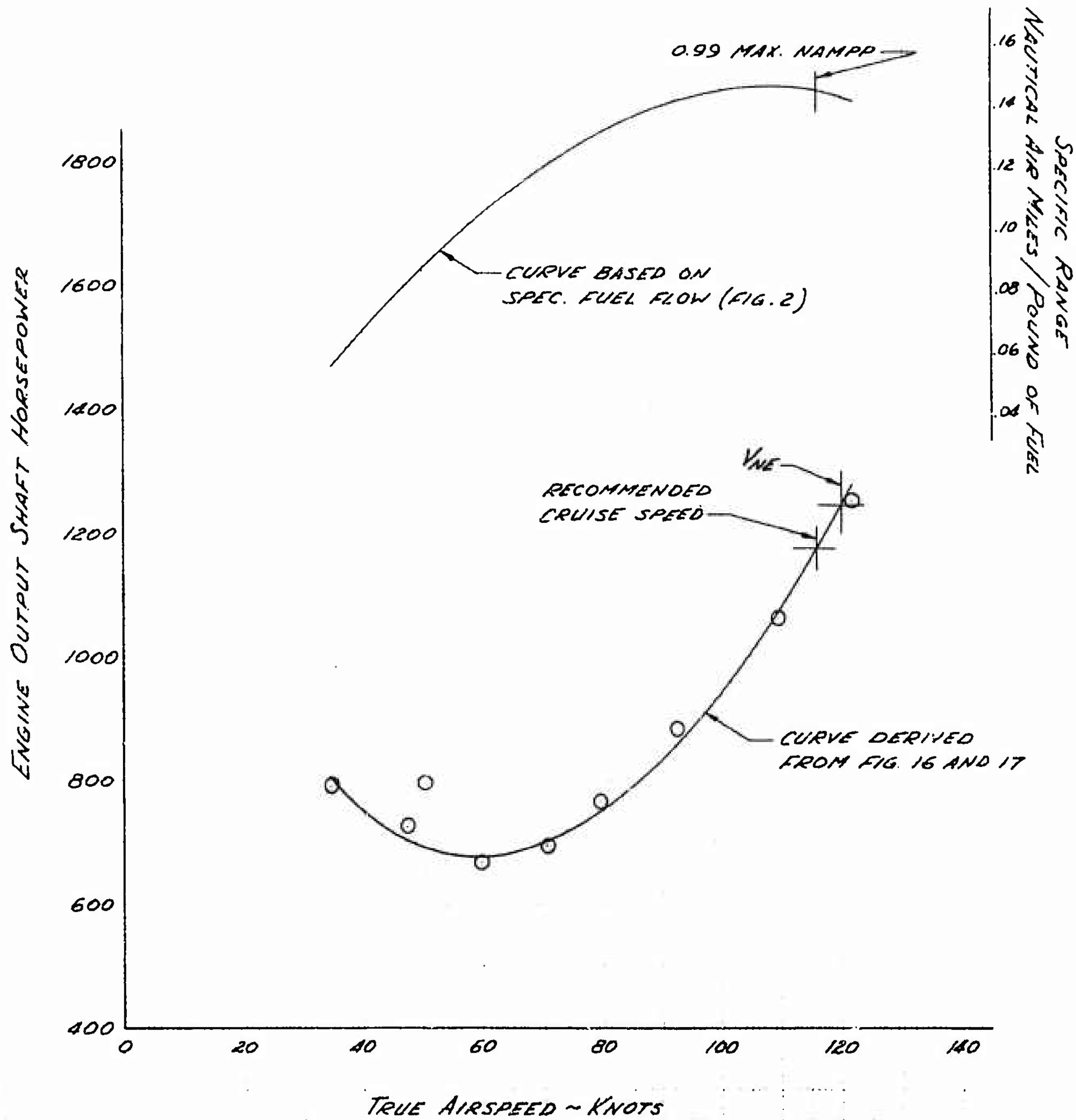

FIGURE NO. 10
LEVEL FLIGHT PERFORMANCE
MODEL 211 S/N N6256N
HUEY TUG

GROSS WEIGHT ~ 9500 LB.
DENSITY ALTITUDE ~ 2930 FT.
ROTOR SPEED ~ 298 RPM
C.G. LOCATION ~ STATION 132.1 (MID)
$C_T \sim 36.48 \times 10^{-4}$
CONFIGURATION ~ CARGO DOORS CLOSED, CARGO MIRROR OFF

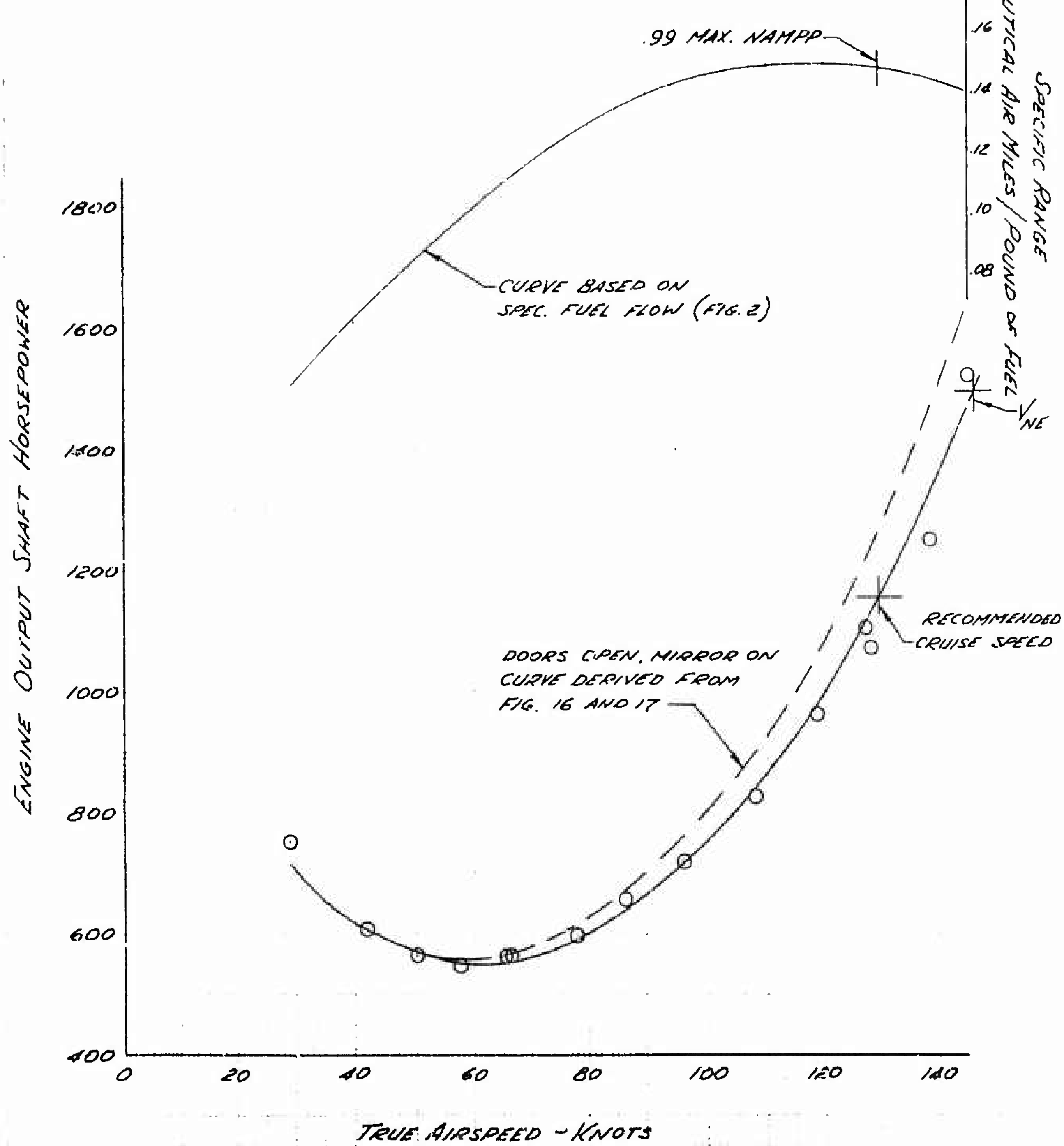

FIGURE NO. 11
LEVEL FLIGHT PERFORMANCE
MODEL 211 S/N N6256N
HUEY TUG

GROSS WEIGHT ~ 9450 LB.
DENSITY ALTITUDE ~ 10,100 FT.
ROTOR SPEED ~ 298 RPM
C.G. LOCATION ~ STATION 132.0 (MID)
C_T ~ 45.22×10^{-4}
CONFIGURATION ~ CARGO DOORS CLOSED, CARGO MIRROR OFF

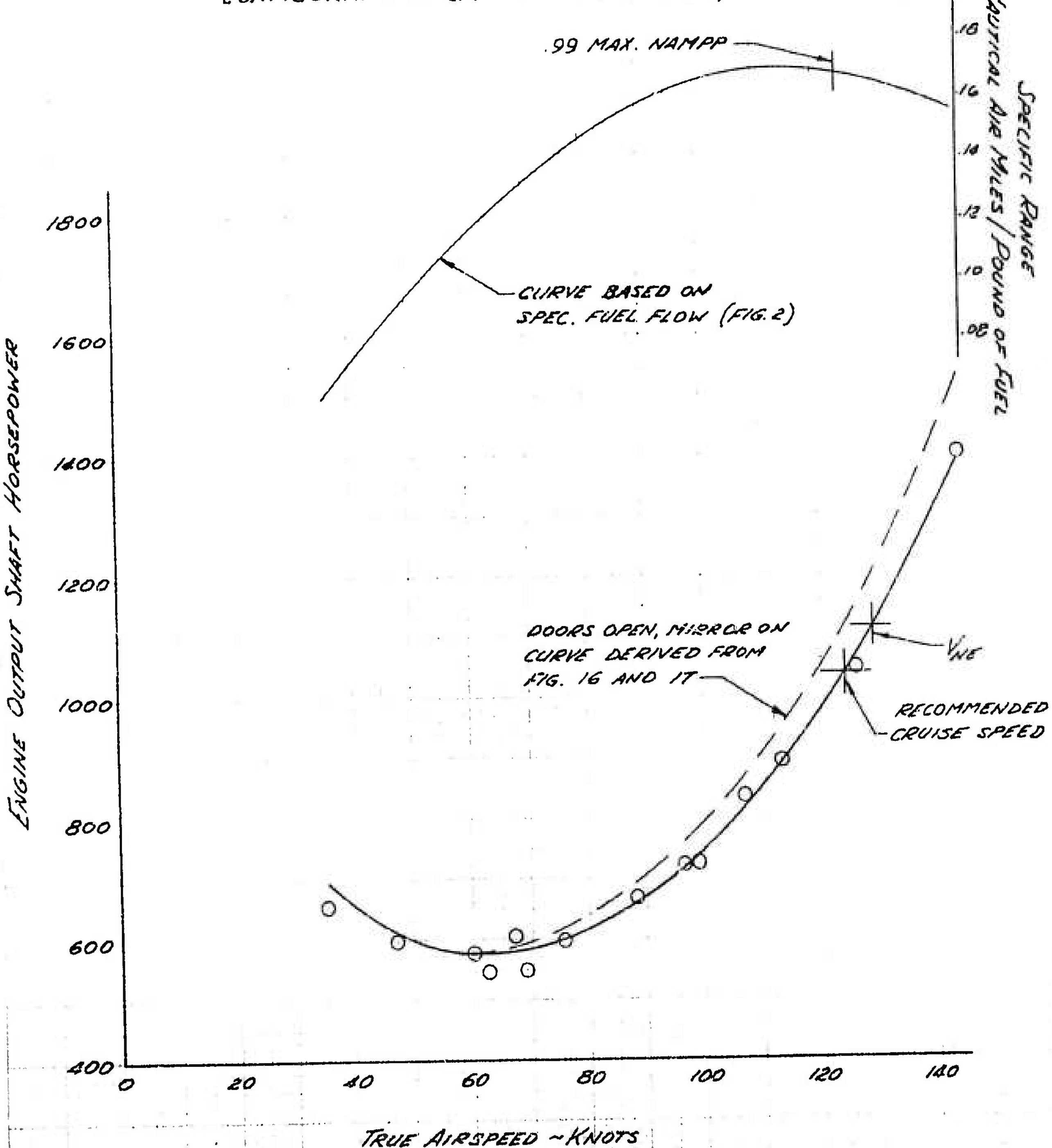

FIGURE NO. 12
LEVEL FLIGHT PERFORMANCE
MODEL 211 S/N N6256N
HUEY TUG

GROSS WEIGHT ~ 7910 LB.
DENSITY ALTITUDE ~ 1500 FT.
ROTOR SPEED ~ 298 RPM
C.G. LOCATION ~ STATION 131.8 (MID)
$C_T \sim 29.00 \times 10^{-4}$
CONFIGURATION ~ CARGO DOORS CLOSED, CARGO MIRROR ON

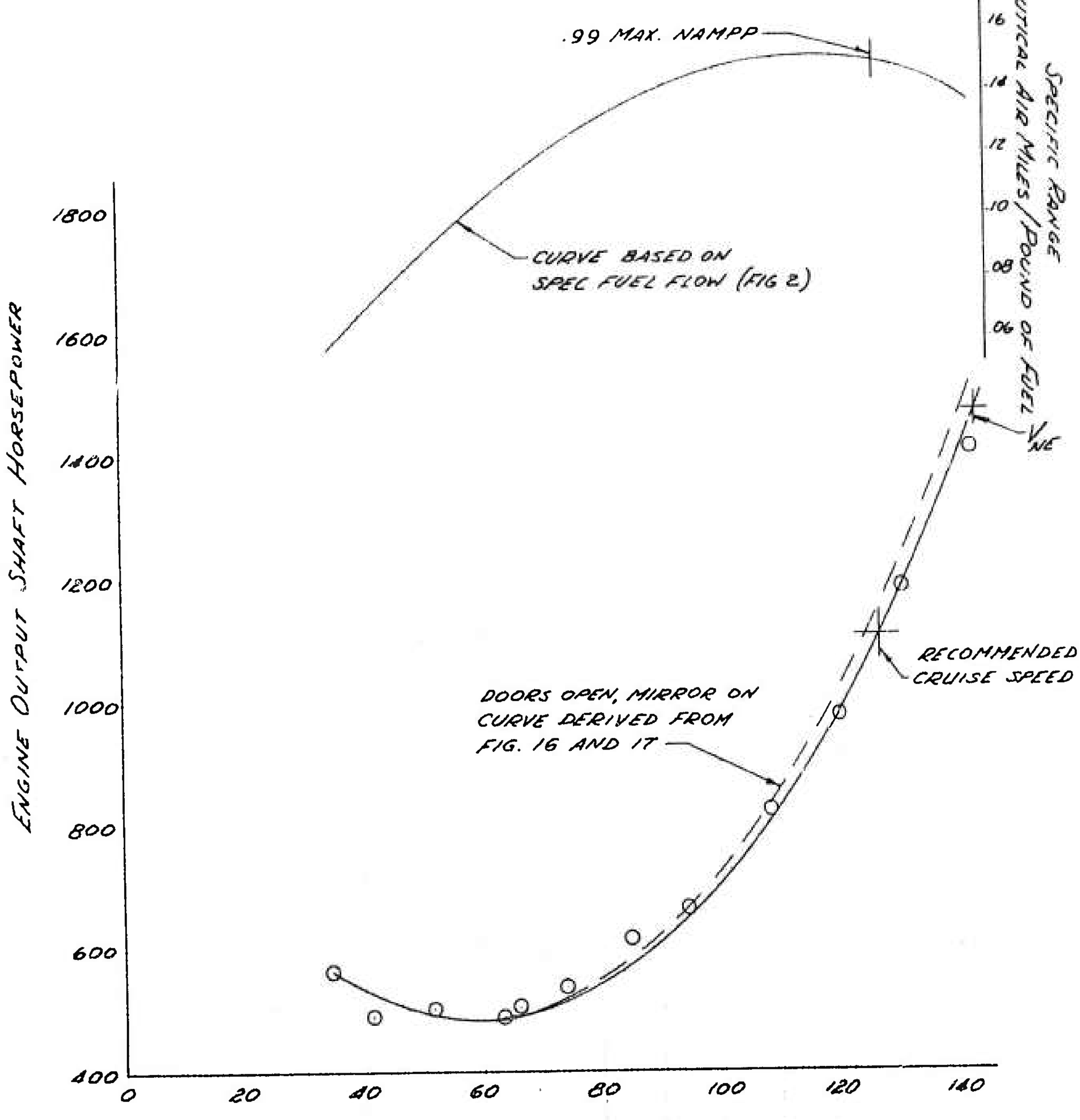

FIGURE NO. 13
LEVEL FLIGHT PERFORMANCE
MODEL 211 S/N N6256N
HUEY TUG

GROSS WEIGHT ~ 9380 LB.
DENSITY ALTITUDE ~ 3300 FT.
ROTOR SPEED ~ 298 RPM
C.G. LOCATION ~ STATION 132.1 (MID)
$C_T \sim 36.40 \times 10^{-4}$
CONFIGURATION ~ CARGO DOORS CLOSED, CARGO MIRROR ON

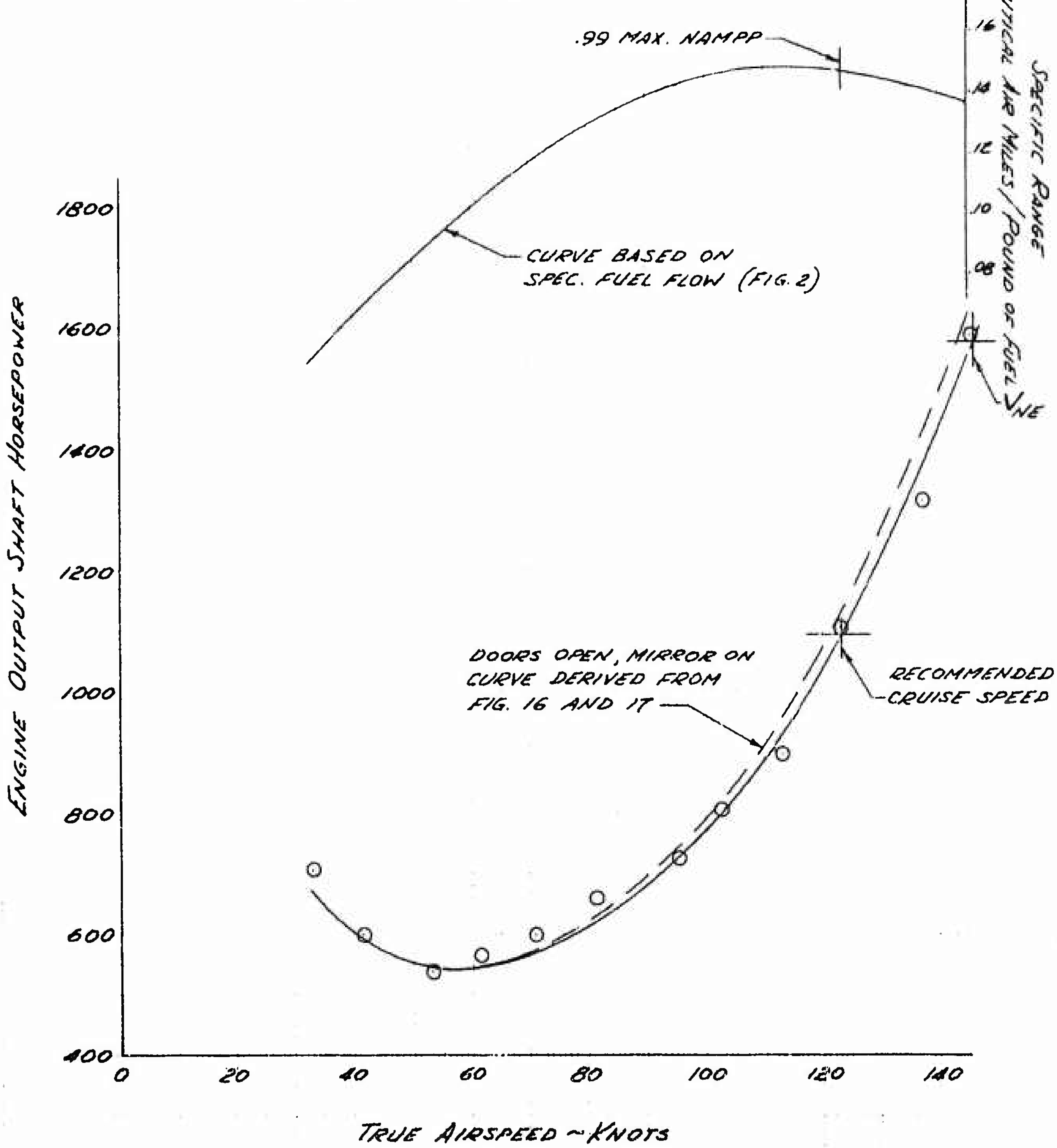

FIGURE NO. 14
LEVEL FLIGHT PERFORMANCE
MODEL 211 S/N N6256N
HUEY TUG

GROSS WEIGHT ~ 12,740 LB.
DENSITY ALTITUDE ~ 4870 FT
ROTOR SPEED ~ 298 RPM
C.G. LOCATION ~ STATION 131.8 (MID)
C_T ~ 51.86×10^{-4}
CONFIGURATION ~ CARGO DOORS OPEN, CARGO MIRROR ON WITH CONEX CONTAINER SLING LOAD

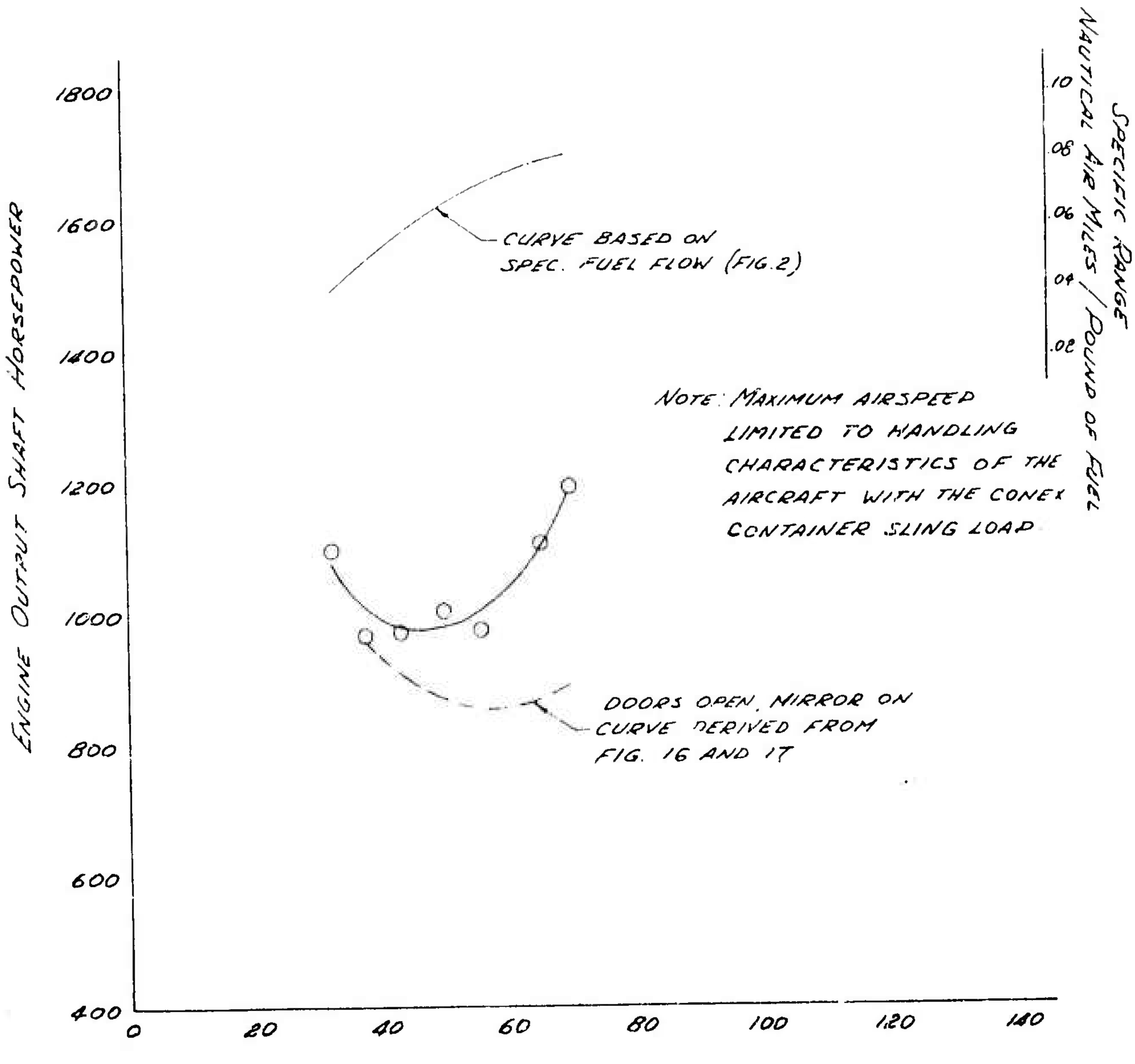

FIGURE NO. 15
LEVEL FLIGHT PERFORMANCE
MODEL 211 S/N N6256N
HUEY TUG

GROSS WEIGHT ~ 13,750 LB.
DENSITY ALTITUDE ~ 1710 FT.
ROTOR SPEED ~ 298 RPM
C.G. LOCATION ~ STATION 131.9 (MID)
$C_T \sim 50.90 \times 10^{-4}$
CONFIGURATION ~ CARGO DOORS OPEN, CARGO MIRROR ON WITH 105 HOWITZER AND 10 ROUNDS OF 105 AMMUNITION SLING LOAD

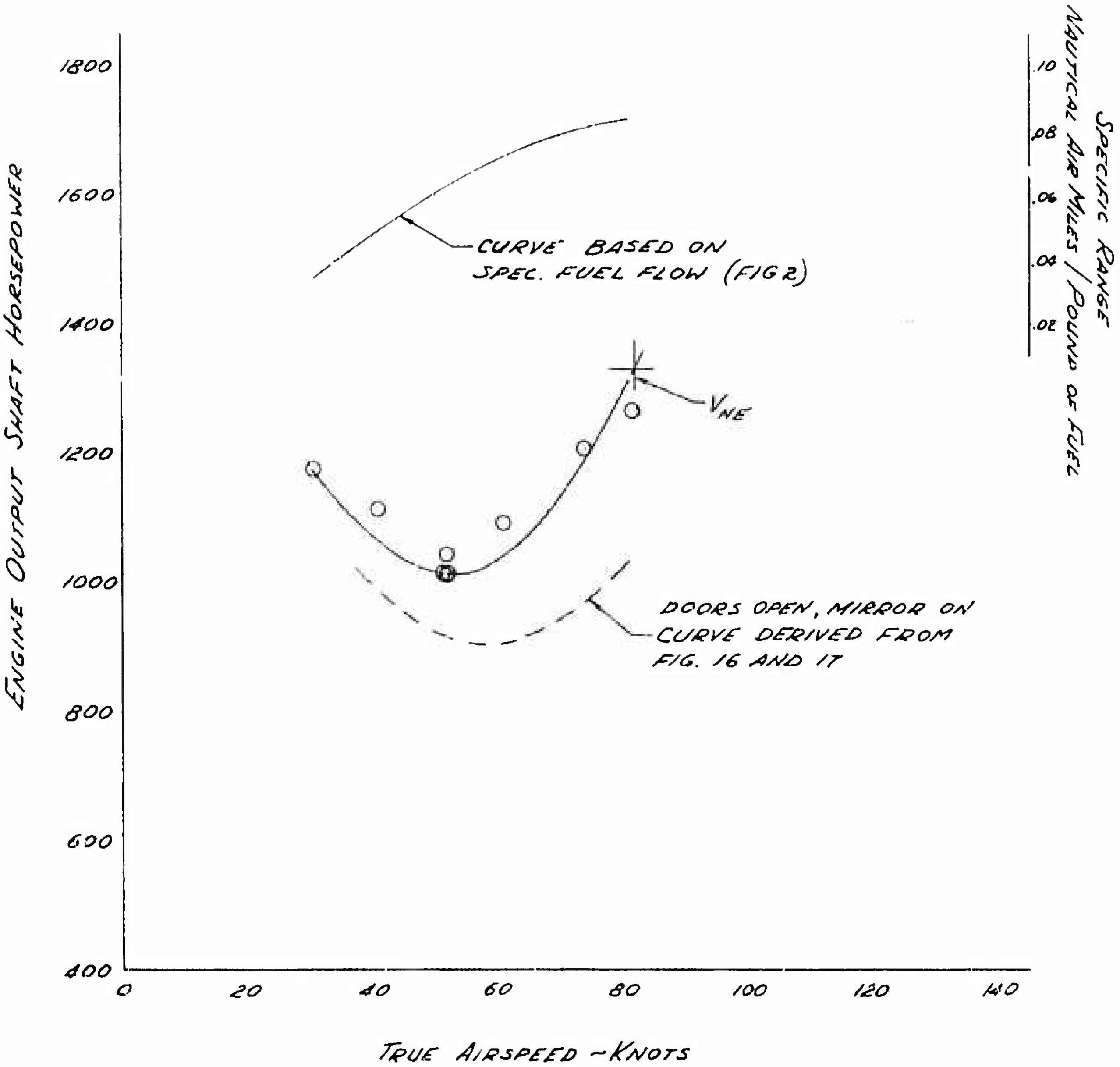

FIGURE NO. 16

NON-DIMENSIONAL LEVEL FLIGHT PERFORMANCE

MODEL 211 S/N N6256N

HUEY TUG

NOTE:

1. POINTS ARE FROM FAIRINGS OF FIG. 5 THRU FIG. 9
2. CARGO DOORS OPEN, CARGO MIRROR ON CONFIGURATION

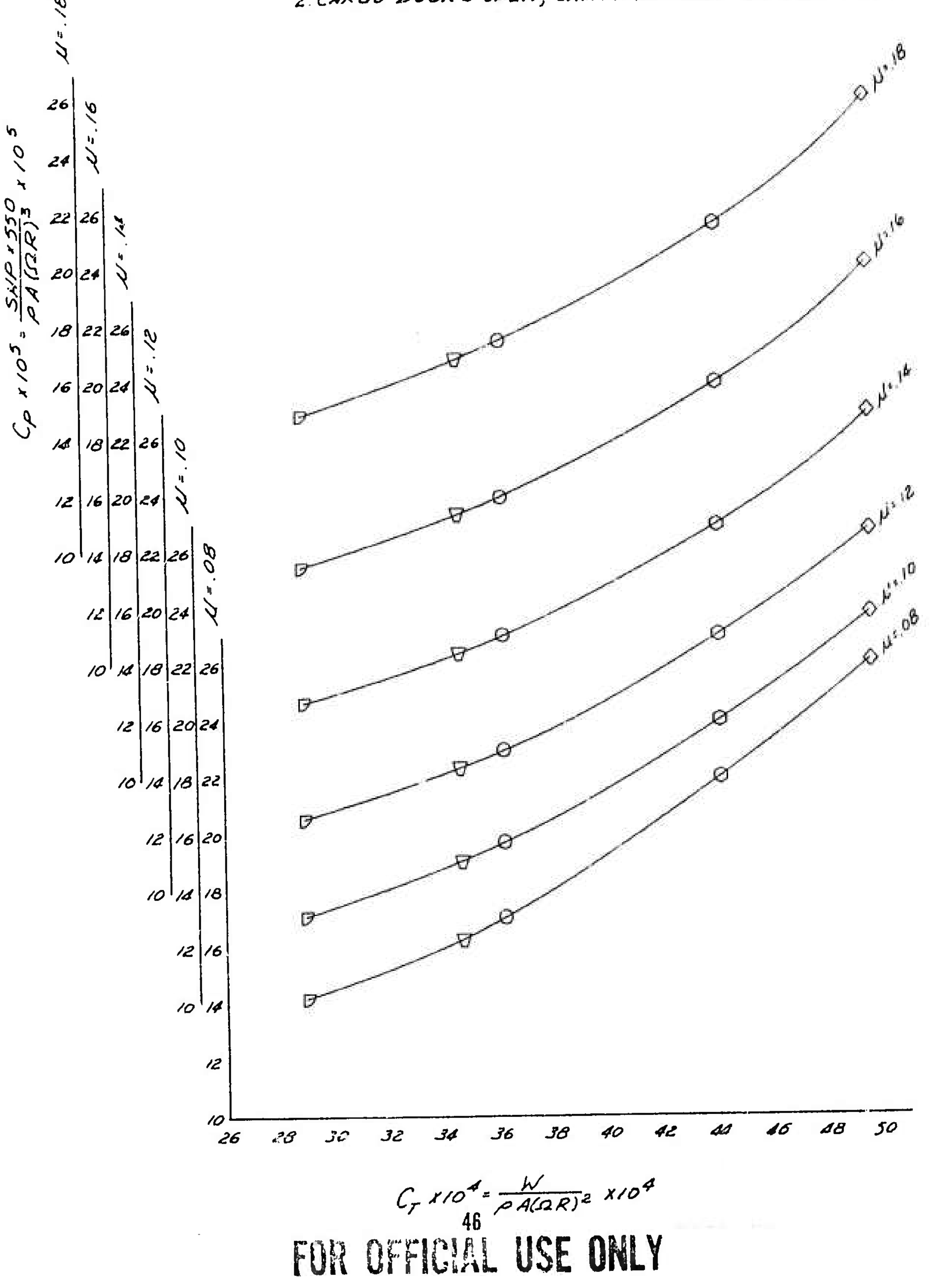

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FIGURE NO. 17

NON-DIMENSIONAL LEVEL FLIGHT PERFORMANCE

MODEL 211 S/N N6256N

HUEY TUG

NOTE:

1. POINTS ARE FROM FAIRINGS OF FIG. 5 THRU FIG. 9
2. CARGO DOORS OPEN, CARGO MIRROR ON CONFIGURATION

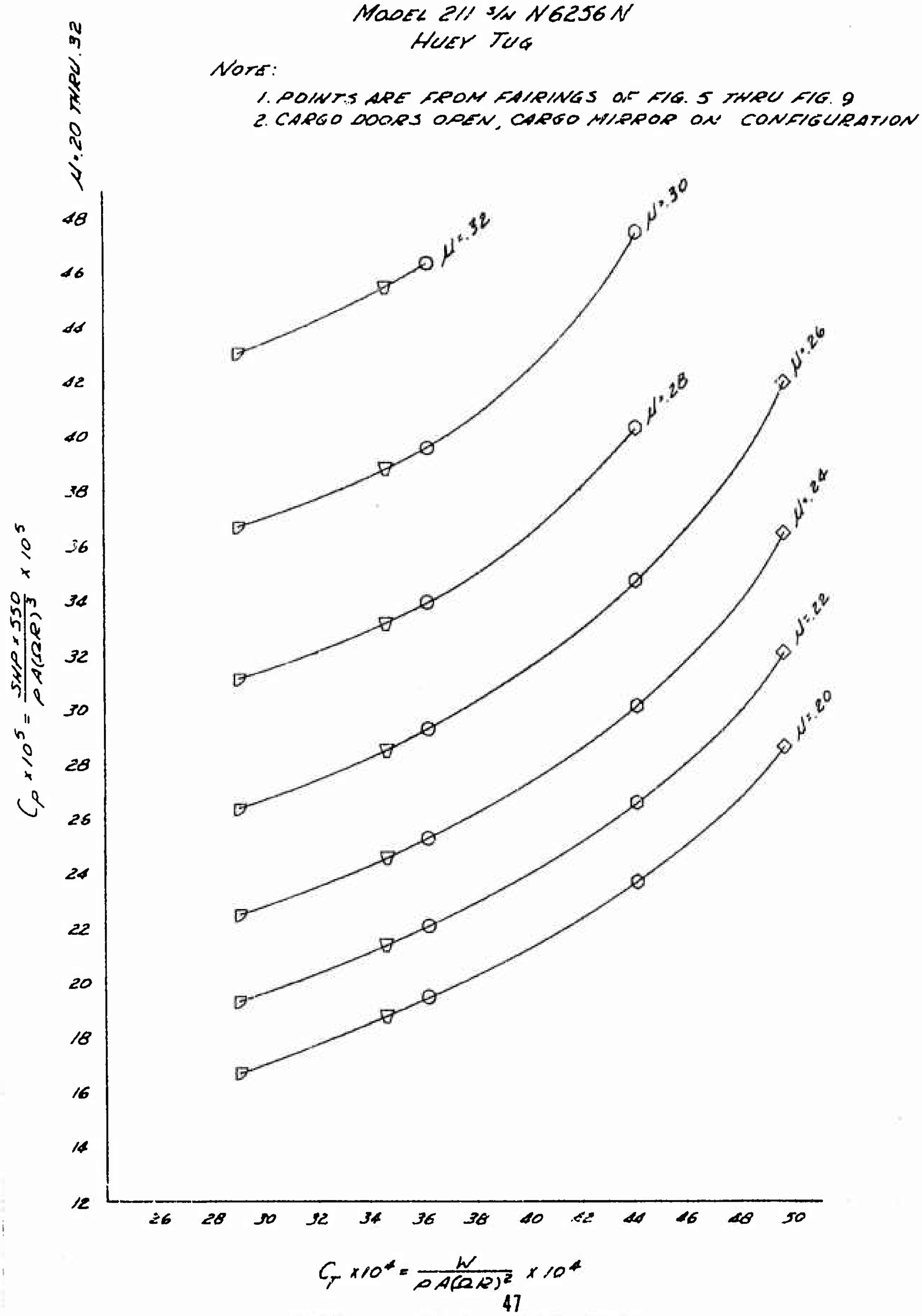

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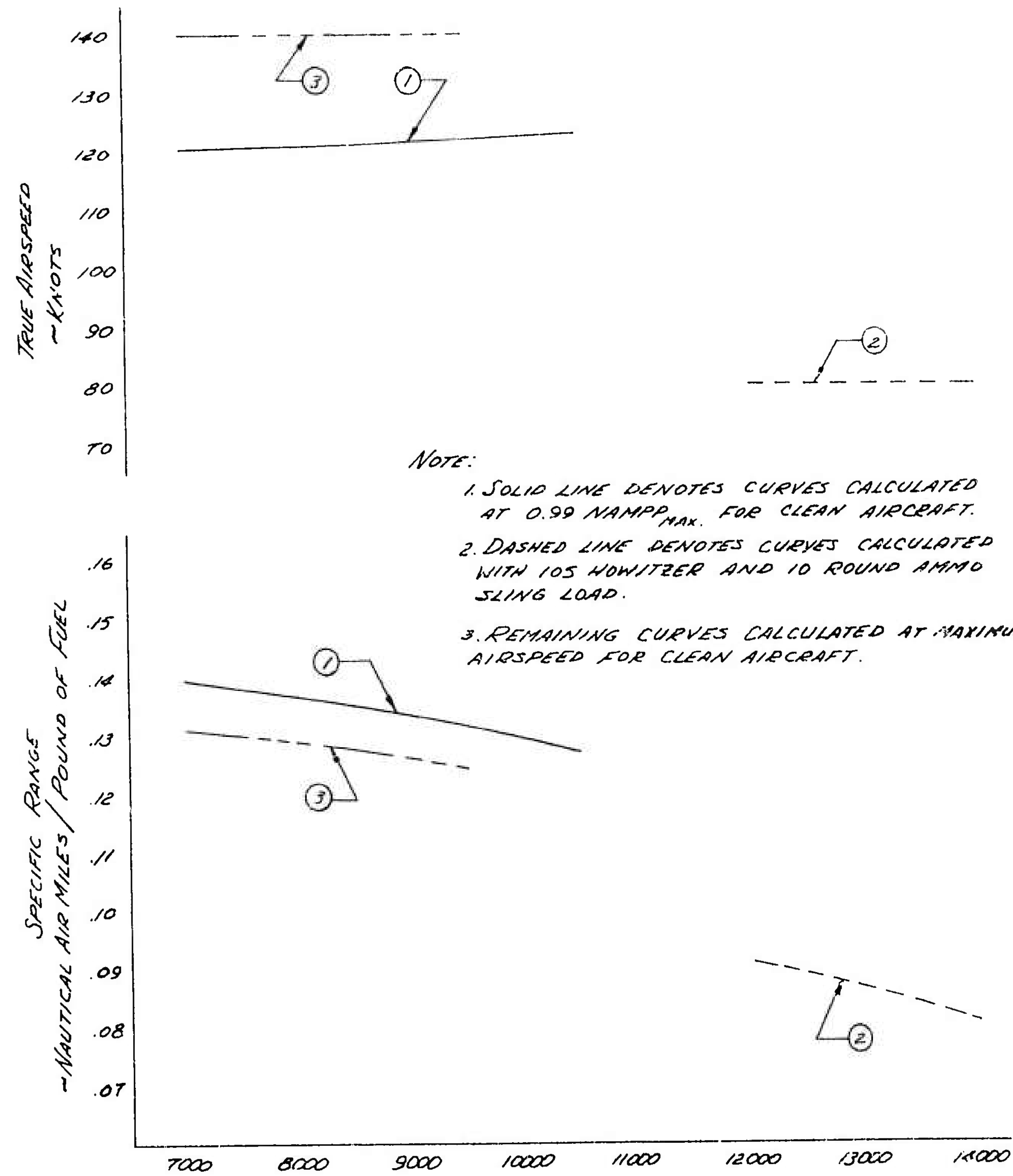
FIGURE NO. 18
RANGE PERFORMANCE
MODEL 211 S/N N6256N
HUEY TUG
ROTOR SPEED ~ 296 RPM
DENSITY ALTITUDE ~ SEA LEVEL



NOTE:
1. SOLID LINE DENOTES CURVES CALCULATED AT 0.99 $NAMPP_{MAX.}$ FOR CLEAN AIRCRAFT.
2. DASHED LINE DENOTES CURVES CALCULATED WITH 105 HOWITZER AND 10 ROUND AMMO SLING LOAD.
3. REMAINING CURVES CALCULATED AT MAXIMUM AIRSPEED FOR CLEAN AIRCRAFT.

FIGURE NO. 19
AUTOROTATIONAL DESCENT
MODEL 211 S/N N6256N
HUEY TUG

SYM	GROSS WEIGHT ~LB.	DENSITY ALTITUDE ~FT.	ROTOR SPEED ~RPM	C.G. LOCATION ~IN.	CONFIGURATION
○	8000	3000	296.0	132.0	CARGO DOORS OPEN CARGO MIRROR ON
□	10550	3000	296.0	132.0	CARGO DOORS OPEN CARGO MIRROR ON

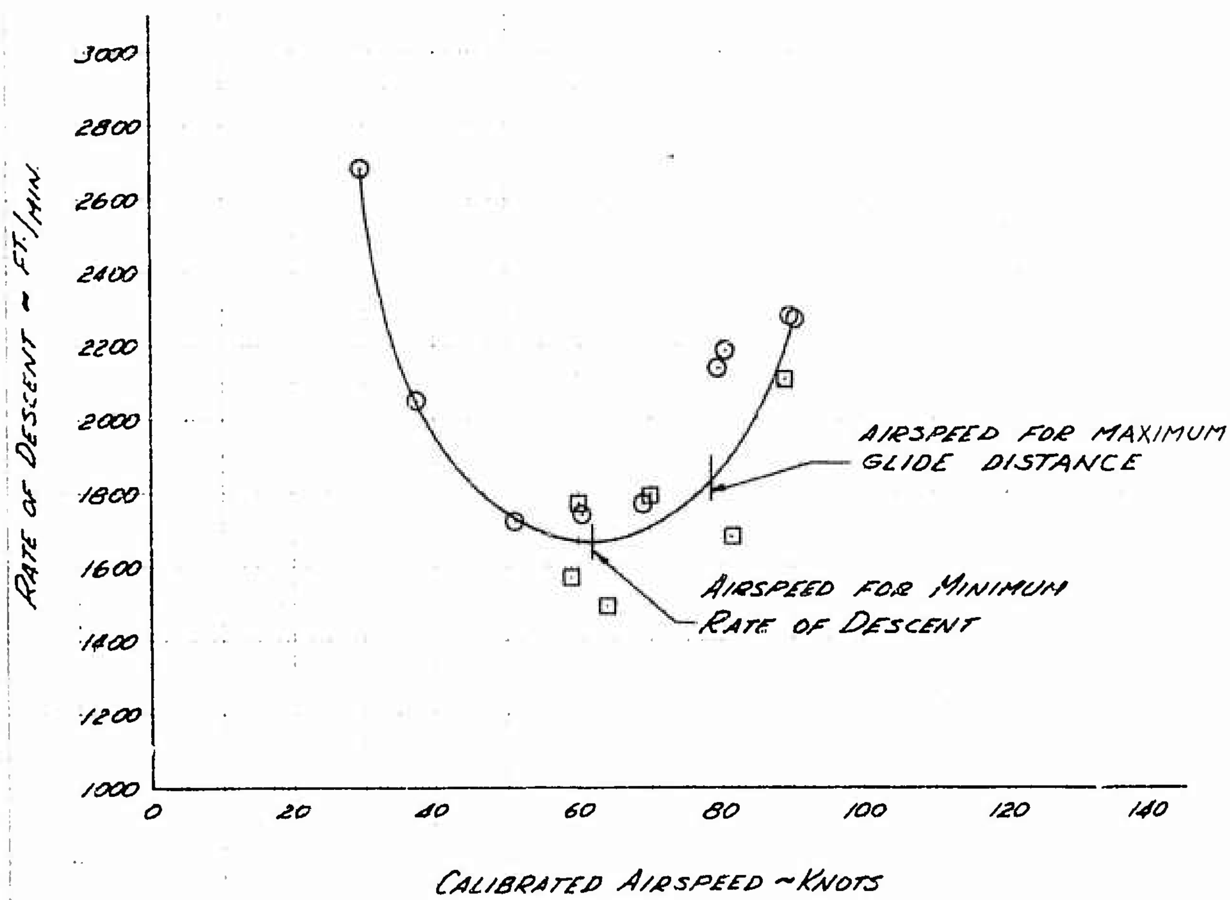


FIGURE NO. 20
AUTOROTATIONAL DESCENT
MODEL 211 S/N N6256N
HUEY TUG

SYM	GROSS WEIGHT ~LB.	DENSITY ALTITUDE ~FT.	TRIM AIRSPEED ~KCAS	C.G. LOCATION ~IN	CONFIGURATION
○	7690	3000	61.5	132.0	CARGO DOORS OPEN CARGO MIRROR ON
□	10140	3000	62.5	132.0	CARGO DOORS OPEN CARGO MIRROR ON

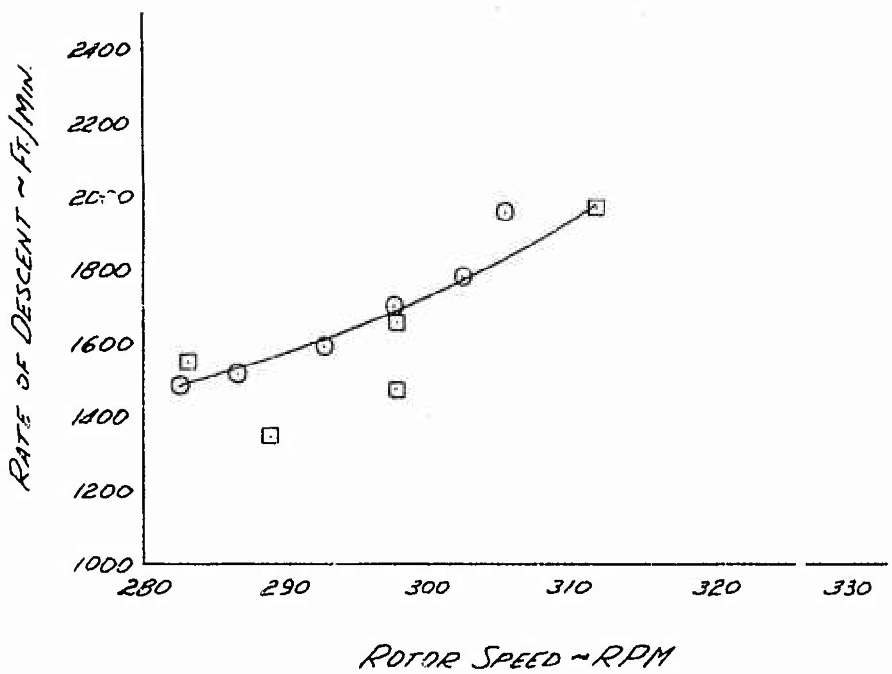


FIGURE NO. 21
AIRSPEED CALIBRATION
MODEL 211 S/N N6256N
BOOM SYSTEM
PACER METHOD
HUEY TUG

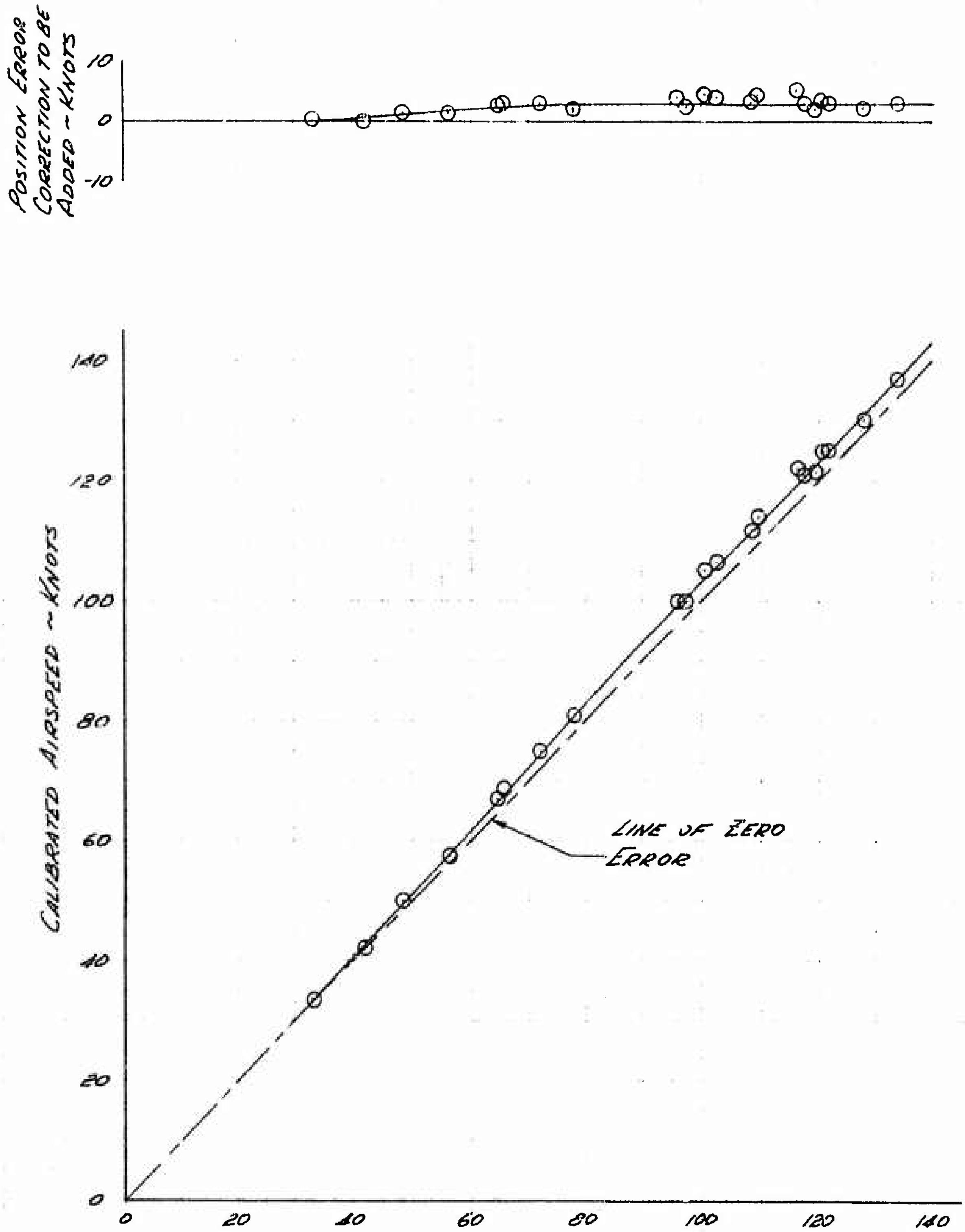


FIGURE No. 22
INLET PERFORMANCE
MODEL 211 S/N 6256N
HUEY TUG

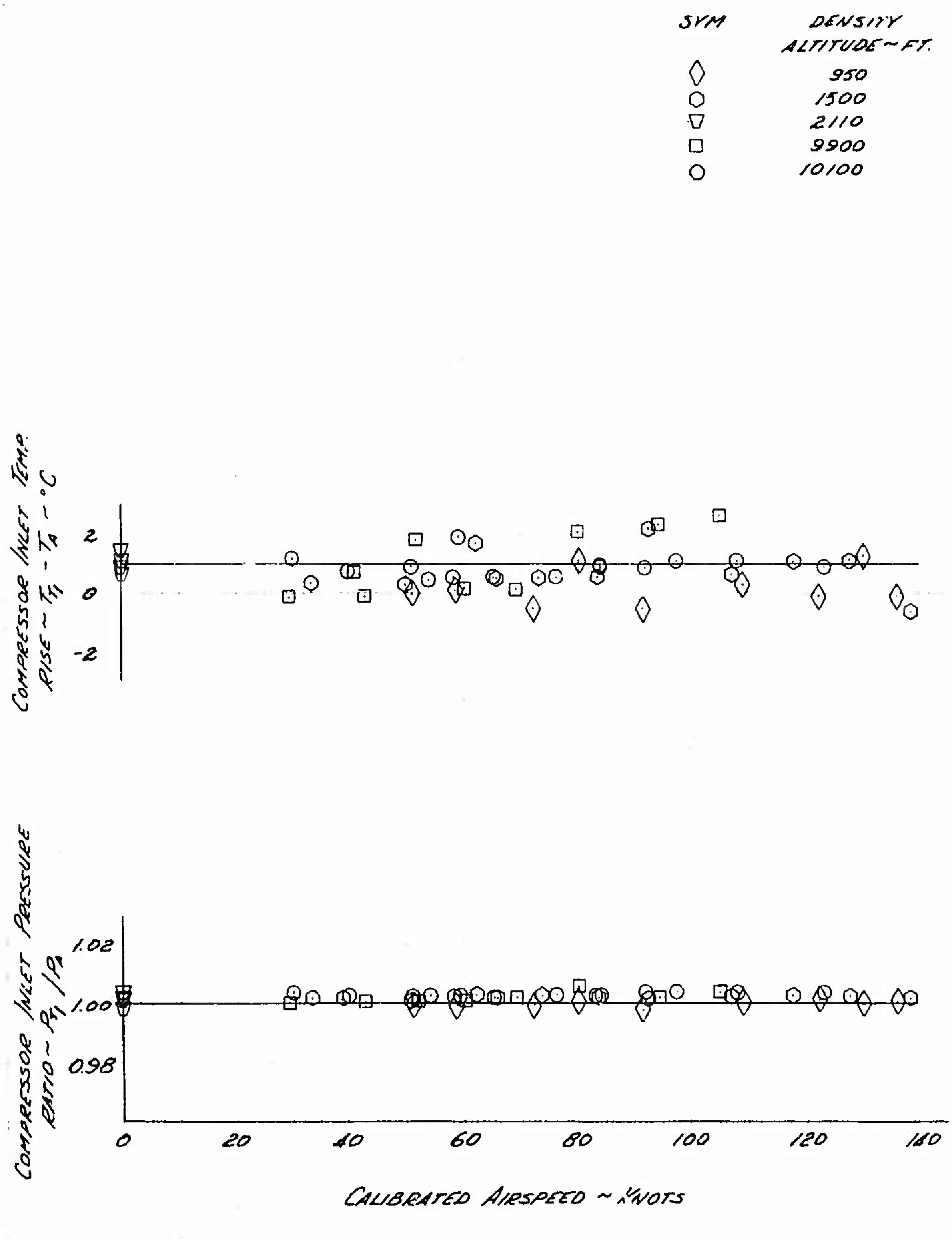


FIGURE No. 23
STATIC LATERAL DIRECTIONAL STABILITY
MODEL 211 S/N N6256N
HUEY TUG

AVG. GROSS WT.	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
8075 LBS.	133.69 IN.	5350 FT.	297 RPM

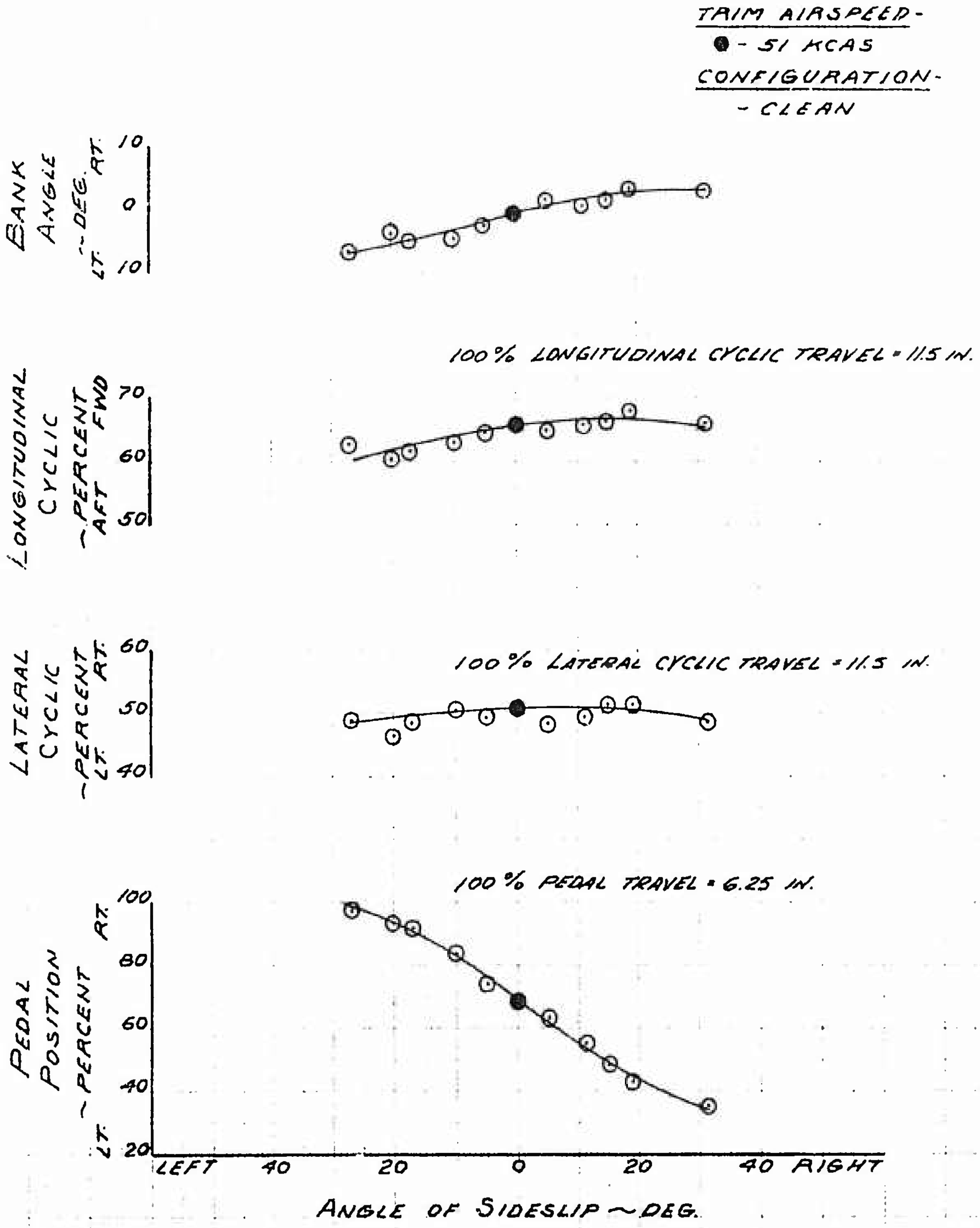


FIGURE No. 24

STATIC LATERAL DIRECTIONAL STABILITY

MODEL 211 S/N N6256N

HUEY TUG

AVG. GROSS WT.	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
7925 LBS.	133.65 IN.	5365 FT	296 RPM

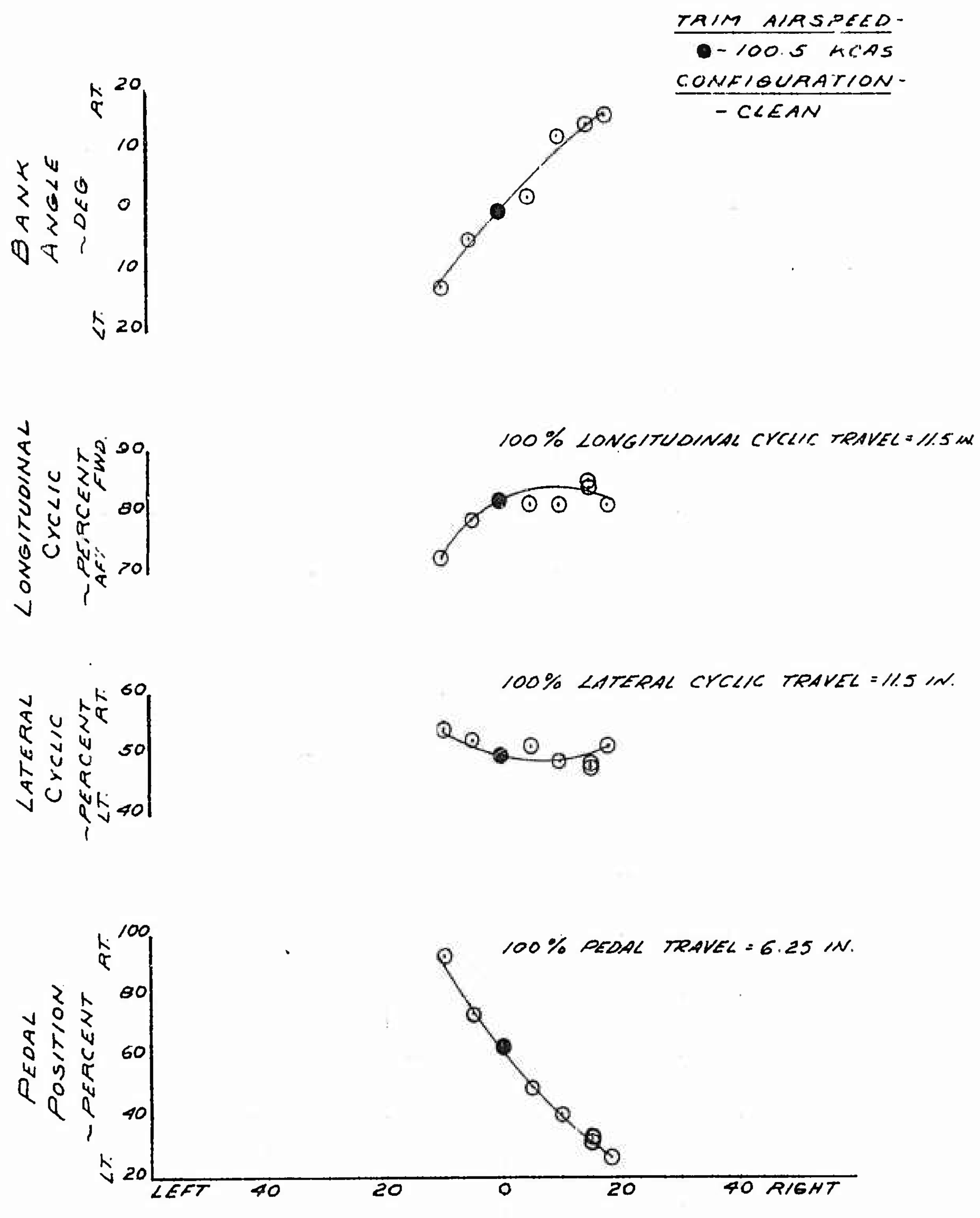


FIGURE No. 25
STATIC LATERAL DIRECTIONAL STABILITY
MODEL 211 S/N N6256N
HUEY TUG

AVG. GROSS WT.	AVG C.G. STATION	AVG. DENSITY ALT	ROTOR SPEED
7805 LBS.	133.64 IN.	5485 FT	296 RPM

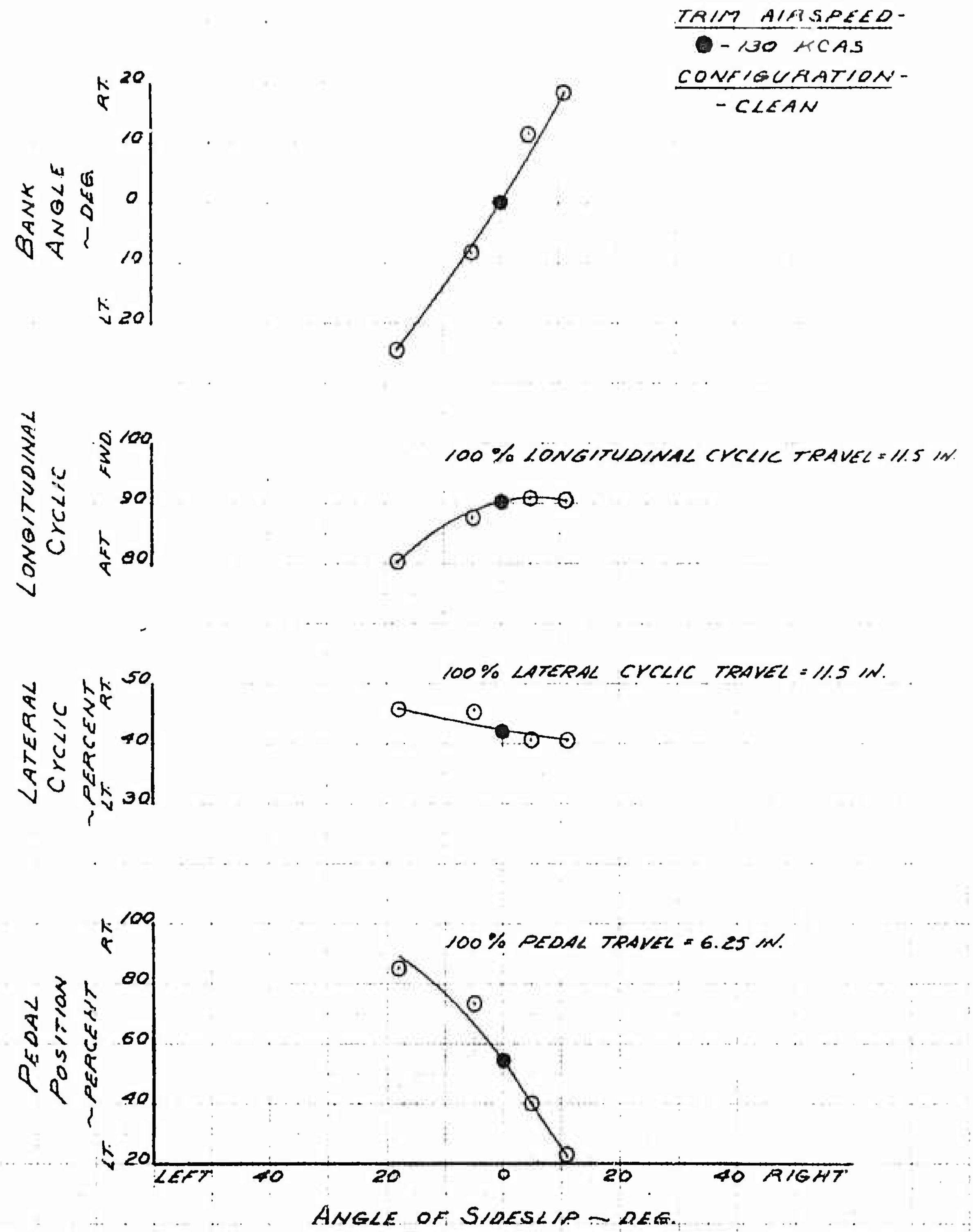


FIGURE No. 26
STATIC LATERAL DIRECTIONAL STABILITY
MODEL 211 S/N N6256N
HUEY TUG

AVG. GROSS WT.	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
7835 LBS	131.75 IN.	4950 FT	298.5 RPM

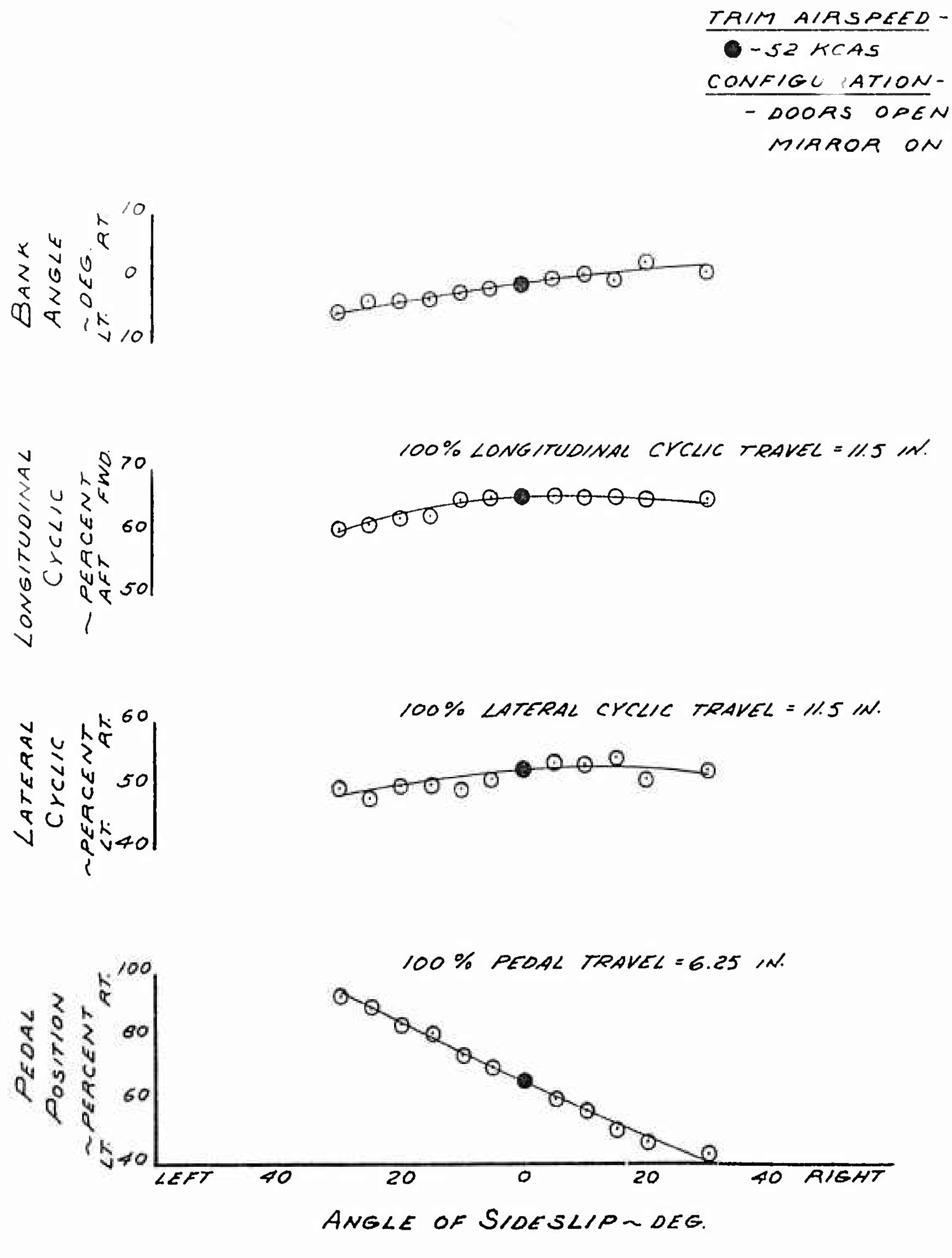


FIGURE No. 27
STATIC LATERAL DIRECTIONAL STABILITY
MODEL 211 S/N N6256N
HUEY TUG

AVG. GROSS WT.	AVG. C.G. STATION	AVG DENSITY ALT.	ROTOR SPEED
7740 LBS	131.69 IN.	5225 FT.	296 RPM

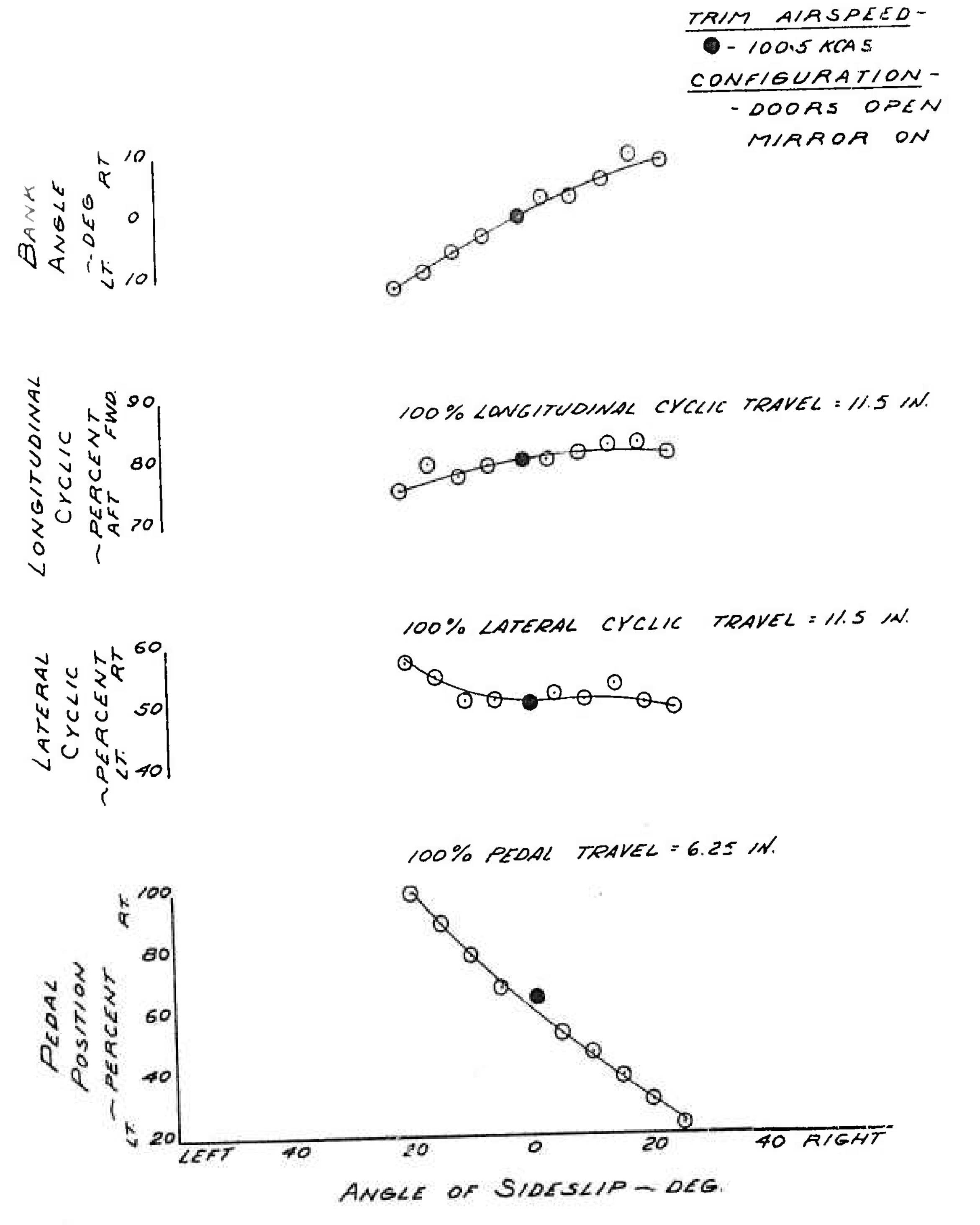


FIGURE No. 28
STATIC LATERAL DIRECTIONAL STABILITY
MODEL 211 S/N N6256N
HUEY TUG

AVG. GROSS WT	AVG. C.G. STATION	AVG. DENSITY ALT	ROTOR SPEED
7650 LBS.	131.65 IN.	5250 FT	296.5 RPM

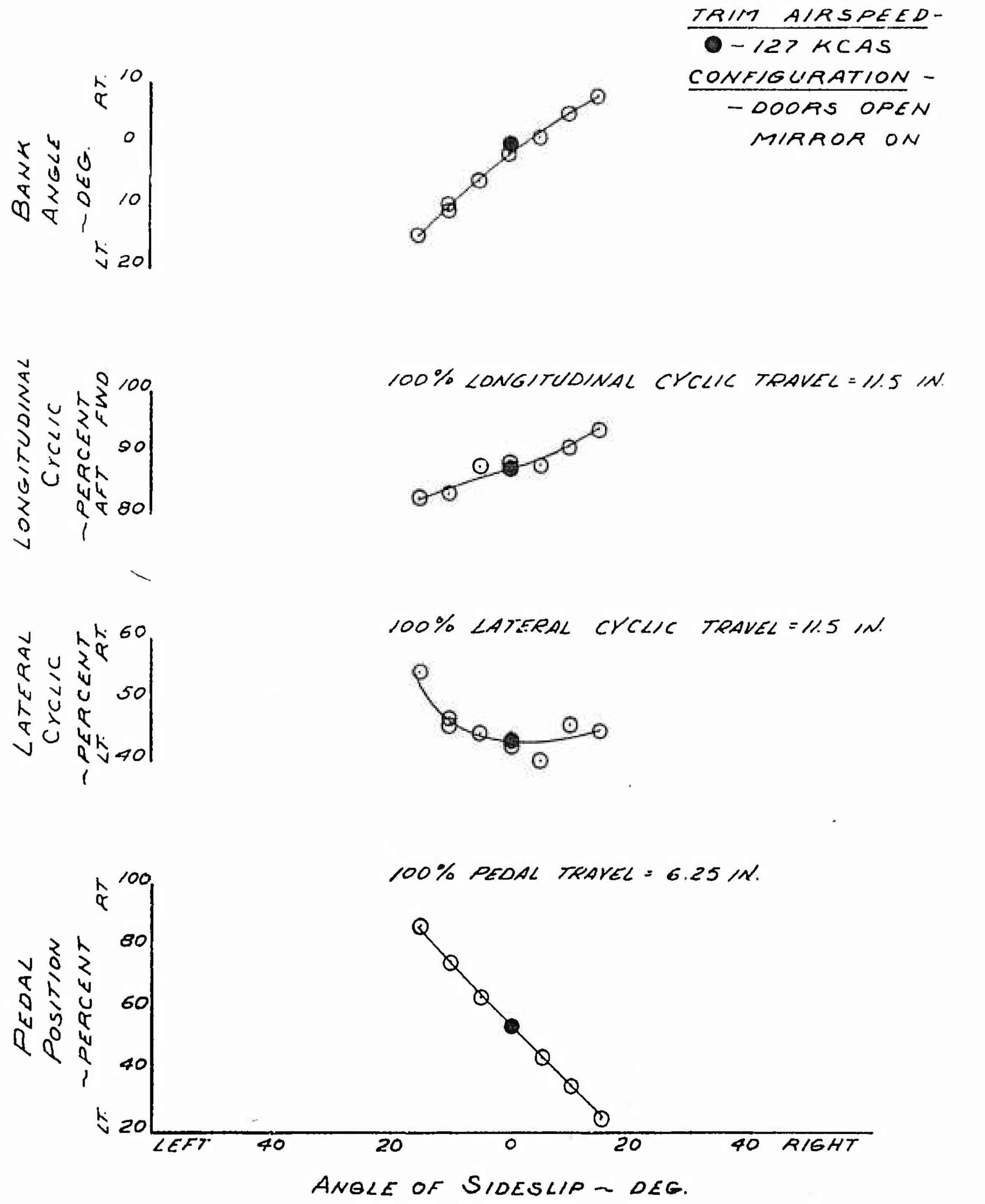


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FIGURE No. 29
STATIC LATERAL DIRECTIONAL STABILITY
MODEL 211 S/N N6256N
HUEY TUG

AVG. GROSS WT	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
9585 LBS.	132.12 IN.	5015 FT	298 RPM

CONFIGURATION -
- CLEAN
TRIM AIRSPEED -
● - 51 KCAS

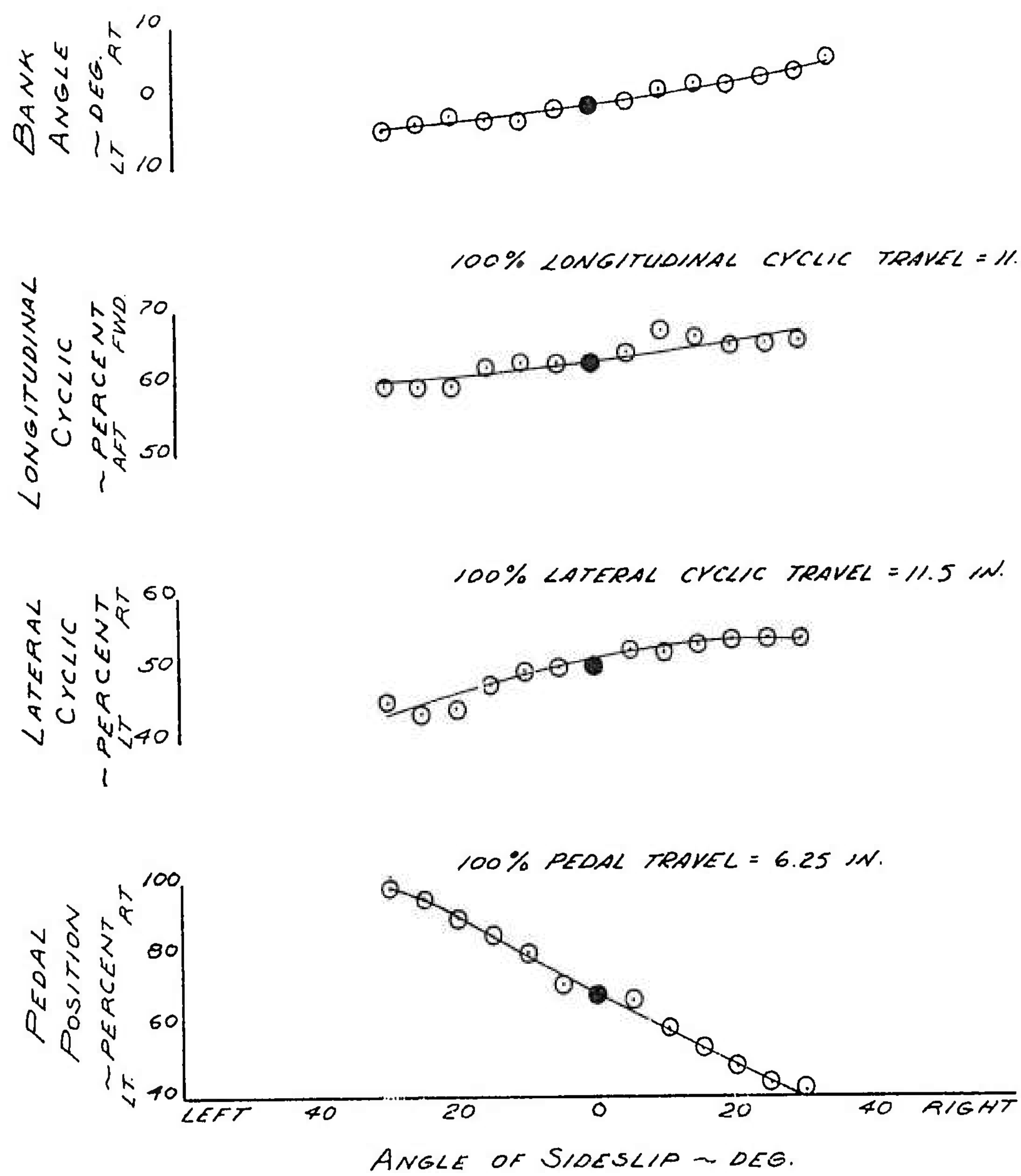

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FIGURE NO. 30
STATIC LATERAL DIRECTIONAL STABILITY
MODEL 211 S/N N6256N
HUEY TUG

AVG. GROSS WT.	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
9445 LBS.	132.06 IN.	5200 FT.	296 RPM

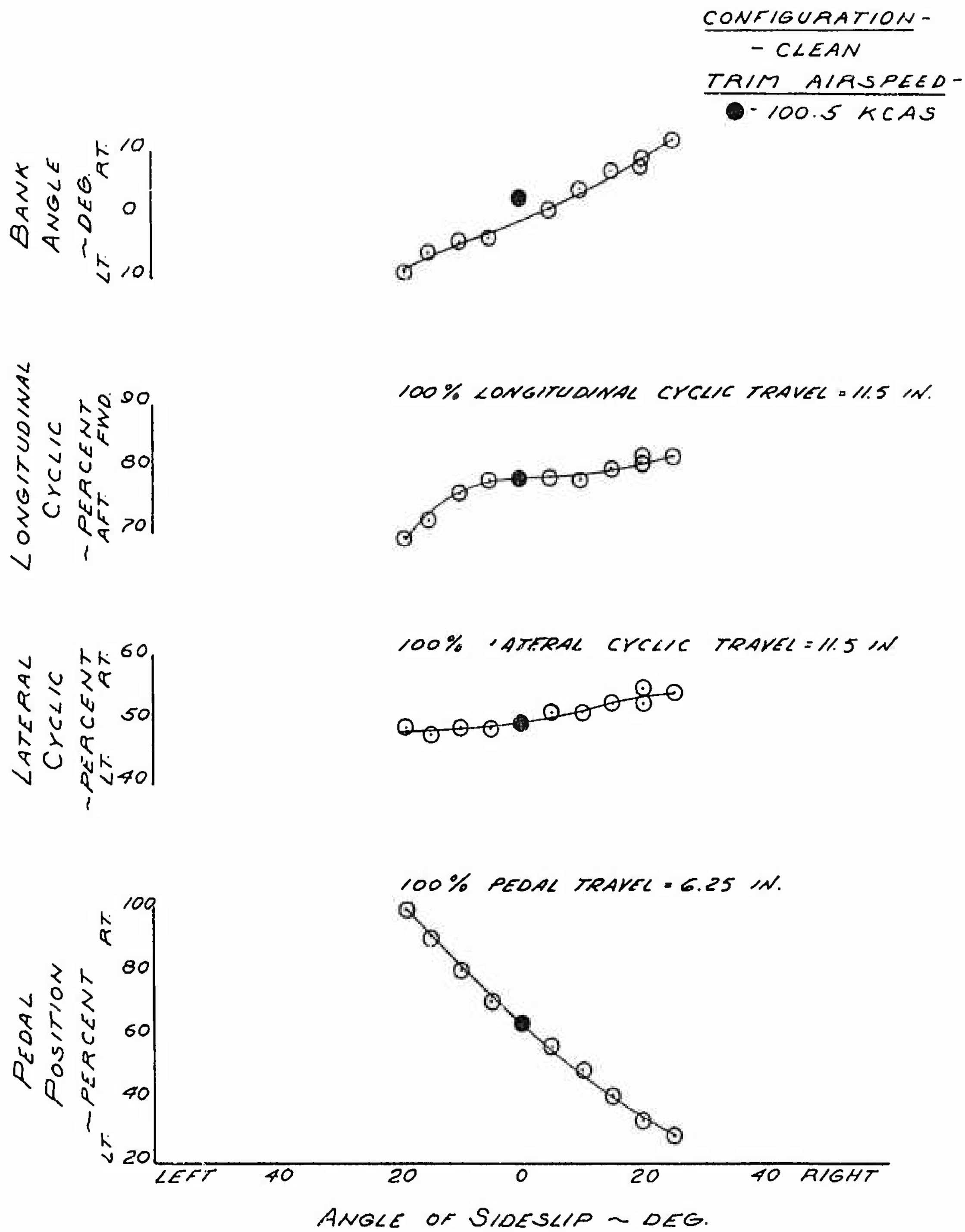

FIGURE No. 31
STATIC LATERAL DIRECTIONAL STABILITY
MODEL 211 S/N N6256N
HUEY TUG

AVG. GROSS WT	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
9325 LBS	132.01 IN.	5180 FT	297 RPM

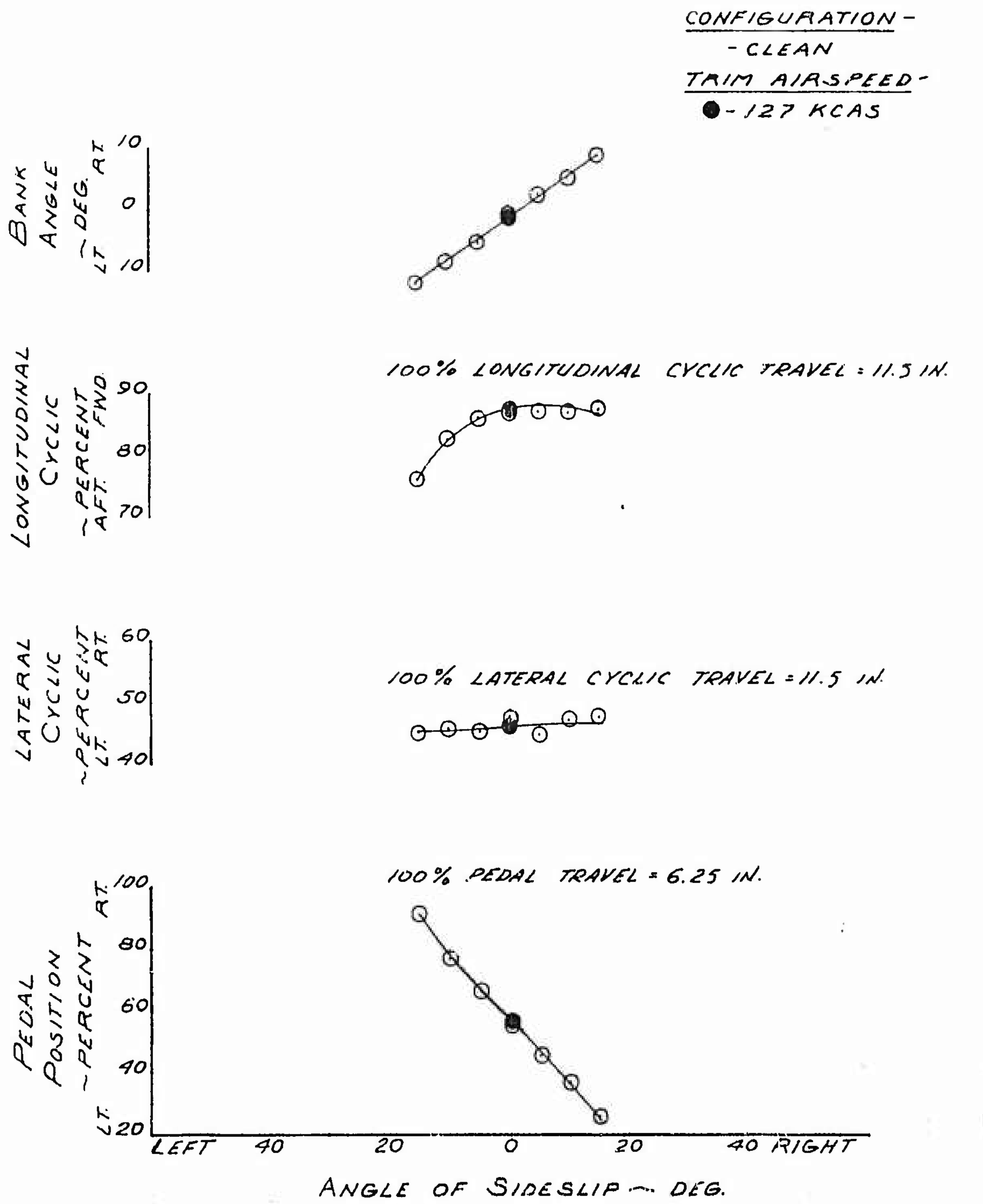

FIGURE No. 32
STATIC LONGITUDINAL STABILITY
MODEL 211 S/N N6256N
MAX. POWER CLIMBS – COLLECTIVE FIXED
HUEY TUG

GROSS WEIGHT ~ 8085 LBS
DENSITY ALTITUDE ~ 5000 FT.
ROTOR SPEED ~ 297 RPM
C.G ~ 133.0 IN.
C_T ~ 33.25×10^{-4}
FLT. COND. ~ DOORS OPEN, MIRROR ON, – CLIMB

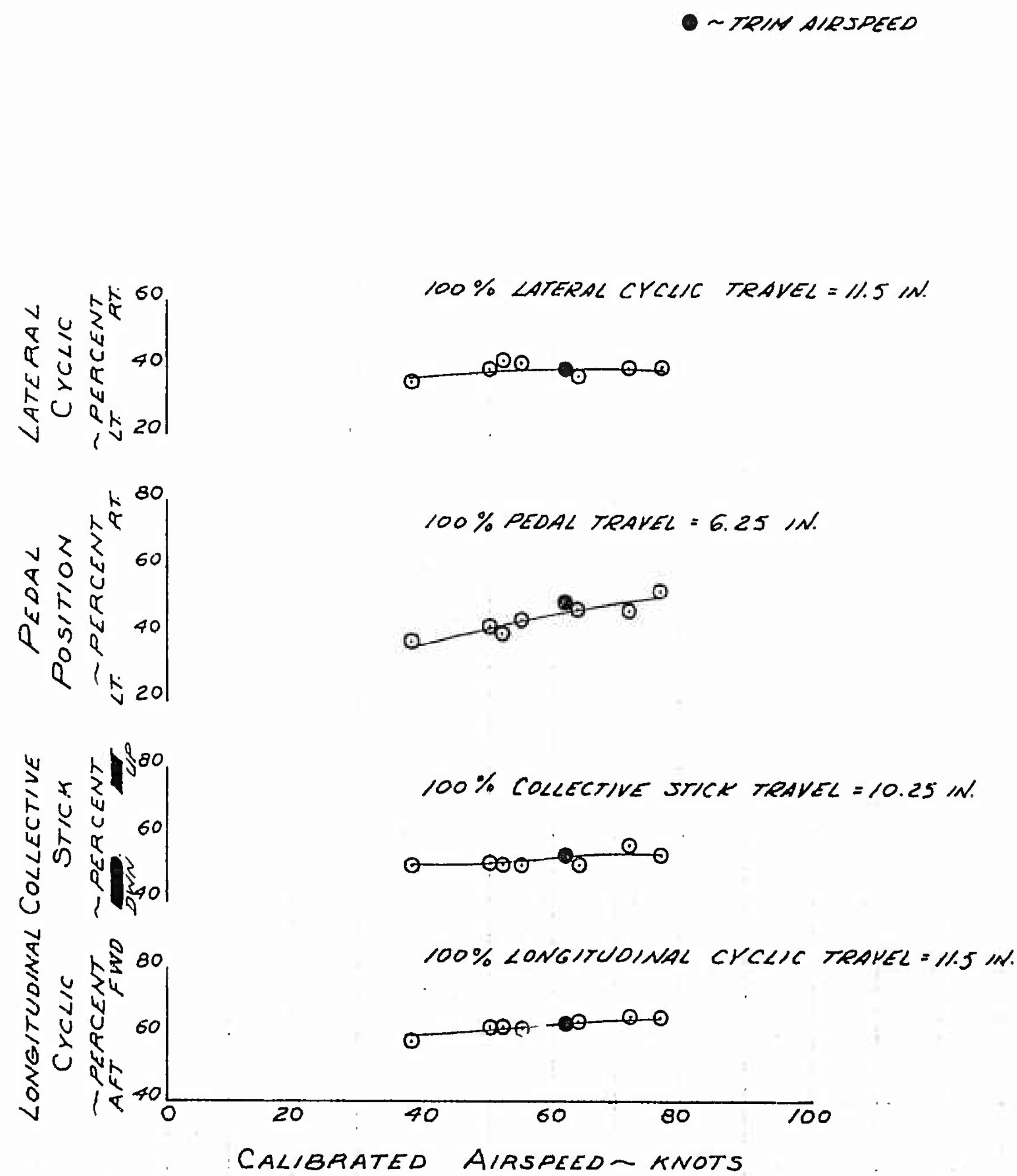

FIGURE No. 33
CONTROL POSITION TRIM CURVES
MODEL 211 S/N N6256N
HUEY TUG

GROSS WEIGHT ~	9390 LBS.
DENSITY ALTITUDE ~	3050 FT.
ROTOR SPEED ~	298 RPM
C.G ~	132.04 IN.
C_T ~	36.20×10^{-4}
FLT. COND. ~	DOORS OPEN, MIRROR ON, LEVEL FLIGHT

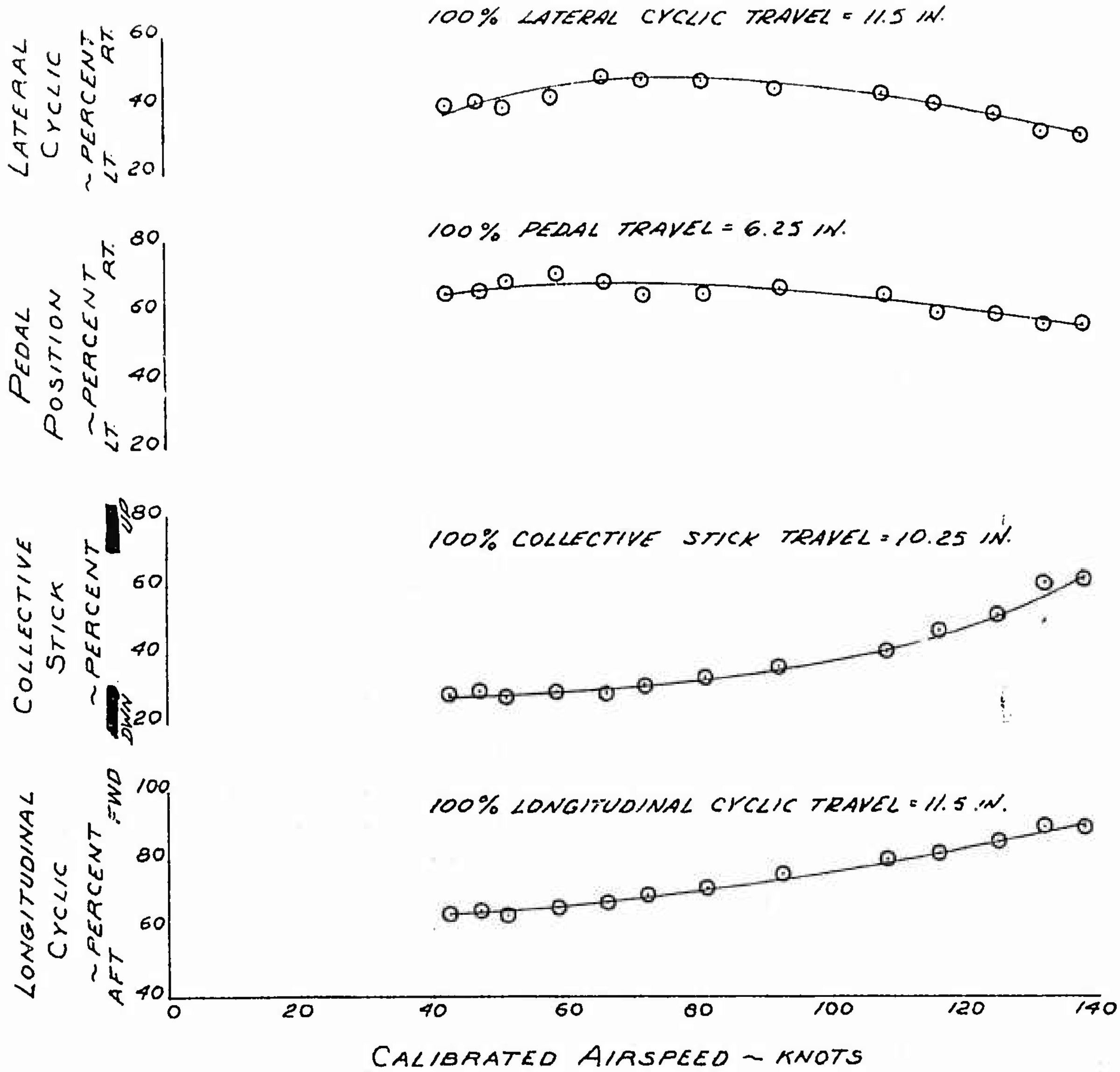

FIGURE No. 34
CONTROL POSITION TRIM CURVES
MODEL 211 S/N N6256N
HUEY TUG

GROSS WEIGHT ~	9500 LBS.
DENSITY ALTITUDE ~	2930 FT.
ROTOR SPEED ~	298.0 RPM
C.G. ~	132.10 IN.
C_T ~	36.48×10^{-4}
FLT. COND. ~	DOORS CLOSED, MIRROR OFF LEVEL FLIGHT

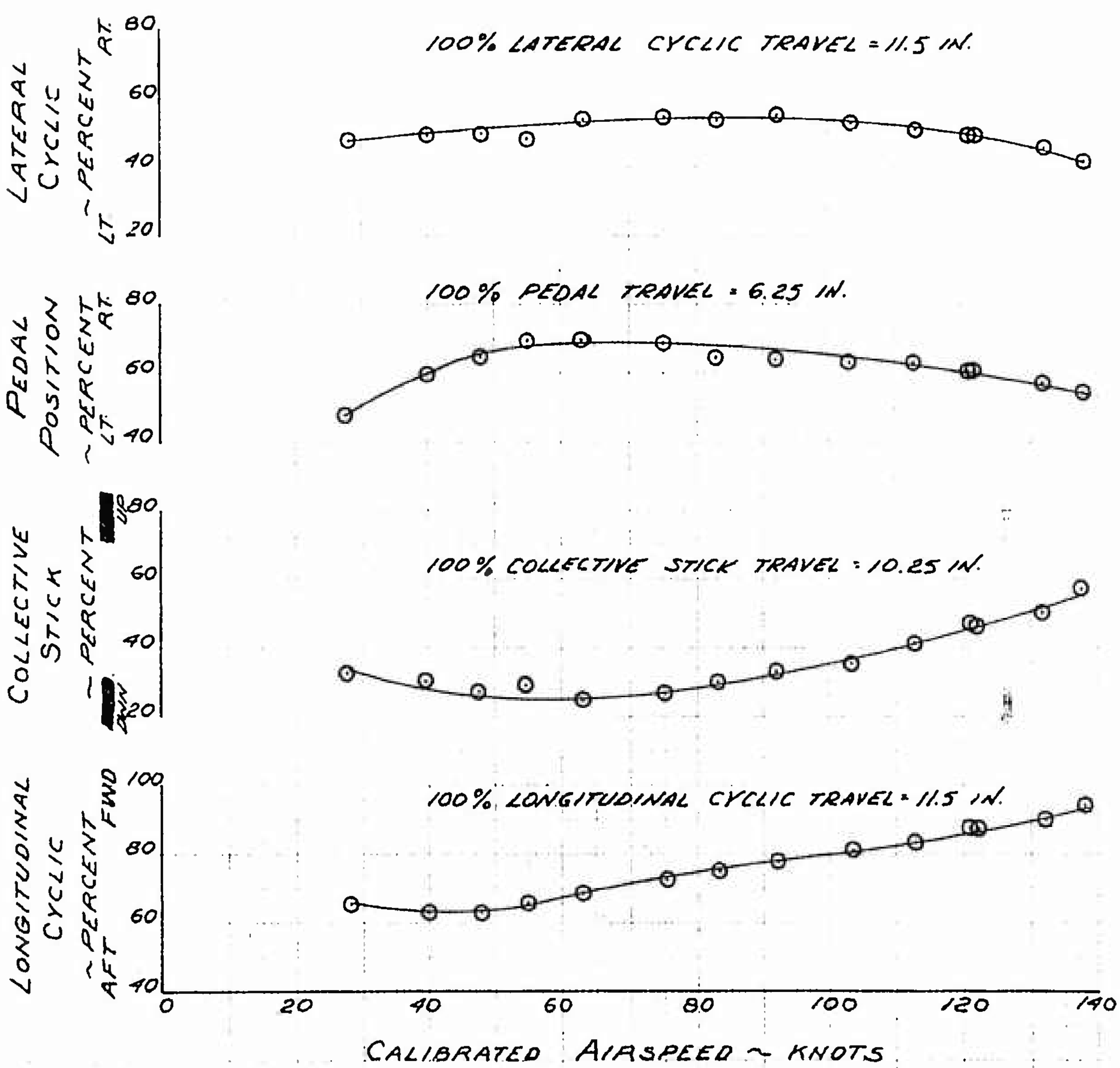

FIGURE No 35

CONTROL POSITION TRIM CURVES

MODEL 211 S/N N6256N

HUEY TUG

GROSS WEIGHT ~	10405 LBS.
DENSITY ALTITUDE ~	6250 FT.
ROTOR SPEED ~	298.0 RPM
C.G. ~	131.86 IN
C_T ~	44.16×10^{-4}
FLT. COND. ~	DOORS OPEN, MIRROR ON LEVEL FLIGHT

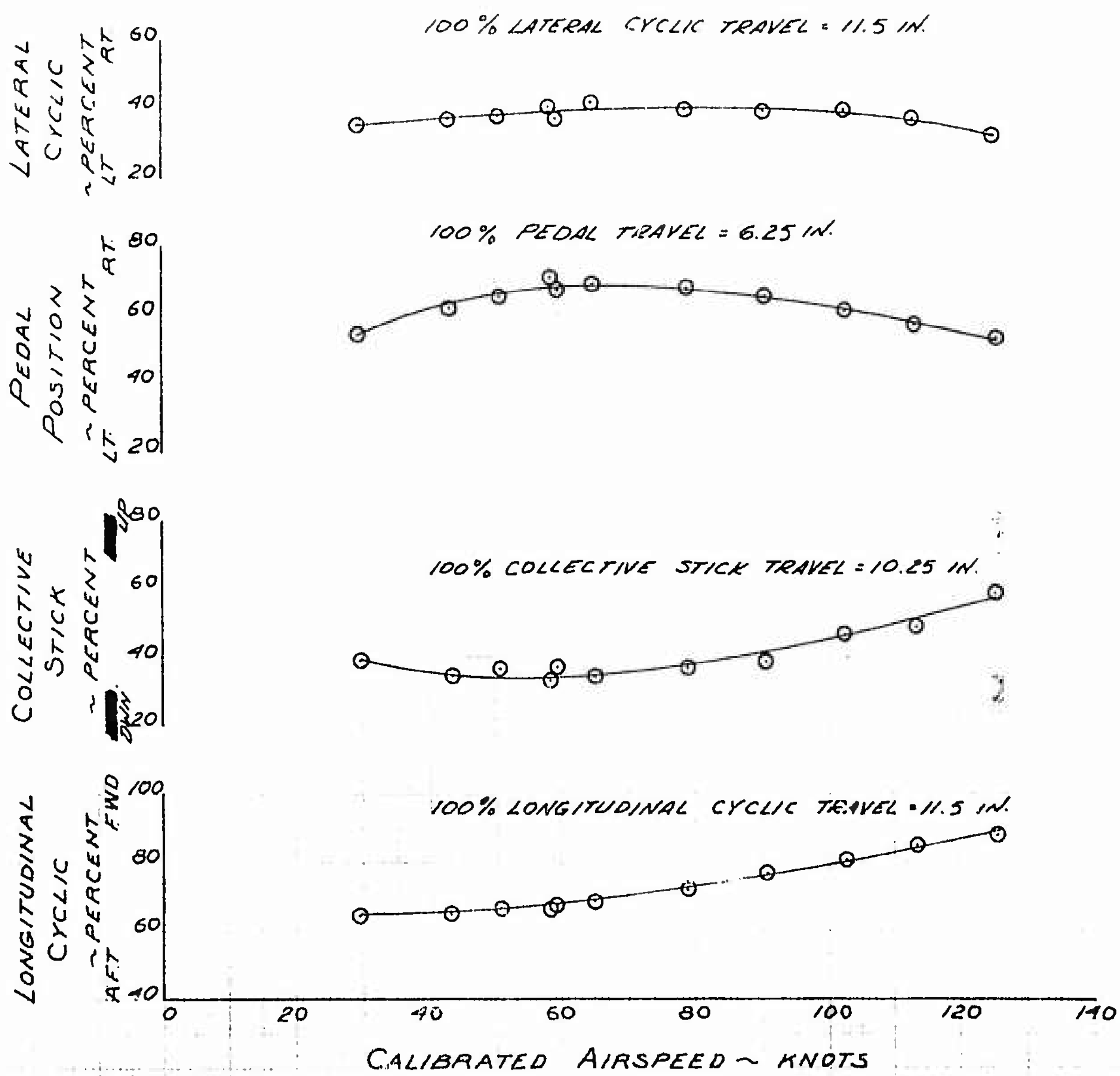

FIGURE No. 36
CONTROL POSITION TRIM CURVES
MODEL 211 S/N N6256N
HUEY TUG

GROSS WEIGHT ~	10450 LBS.
DENSITY ALTITUDE ~	9900 FT.
ROTOR SPEED ~	298.0 RPM
C.G. ~	131.90 IN
C_T ~	49.67×10^{-4}
FLT COND ~	DOORS OPEN, MIRROR ON LEVEL FLIGHT

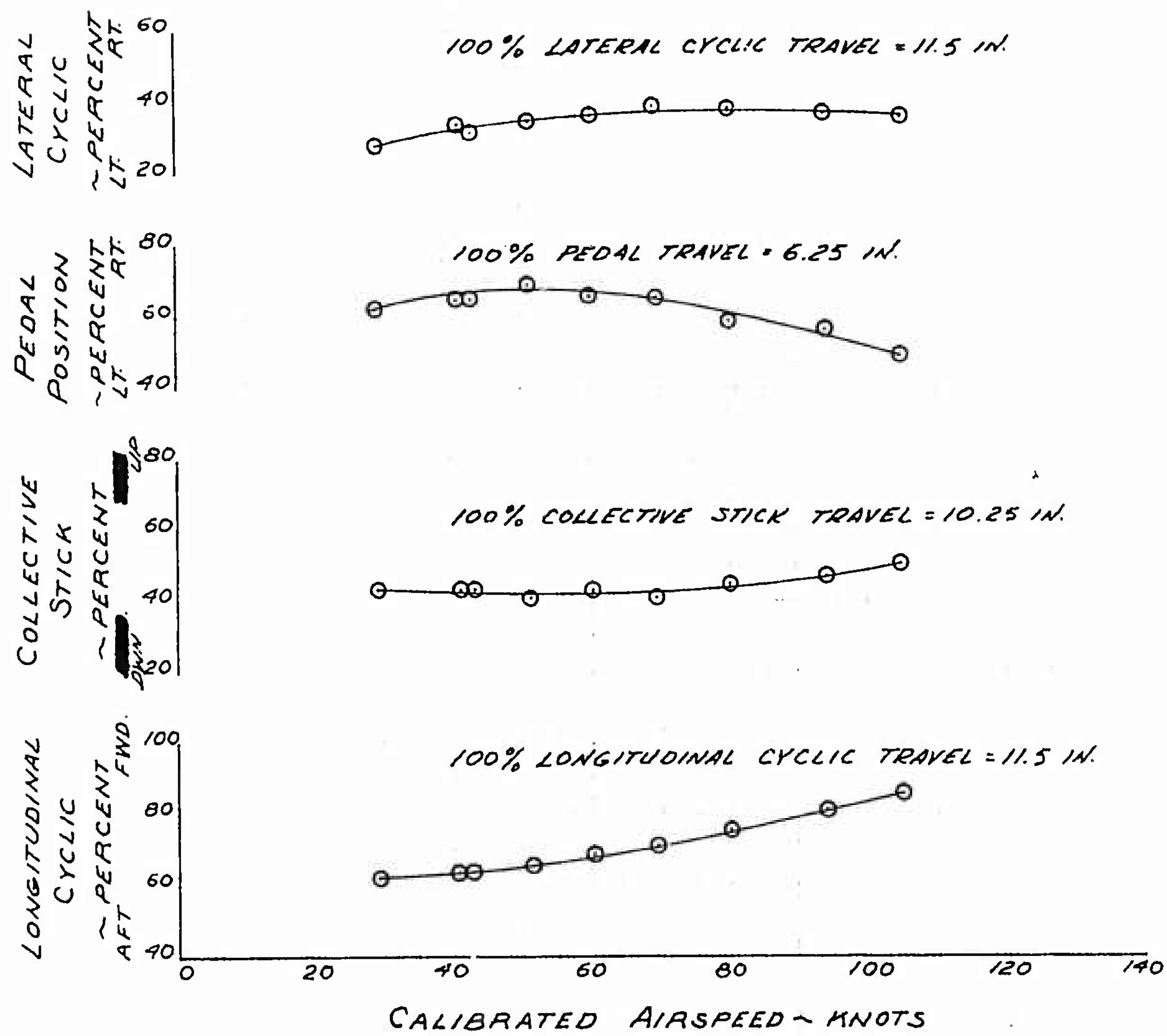

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FIGURE NO 37
CONTROL POSITION TRIM CURVES
MODEL 211 S/N N6256N
HUEY TUG

GROSS WEIGHT ~	13750 LBS.
DENSITY ALTITUDE ~	1710 FT
ROTOR SPEED ~	298 RPM
C.G. ~	131.92 IN.
C_T ~	50.90×10^{-4}
FLT. COND. ~	DOORS OPEN, MIRROR ON, SLING LOAD (105 HOWITZER AND 10 ROUNDS OF 105 AMMUNITION), LEVEL FLIGHT

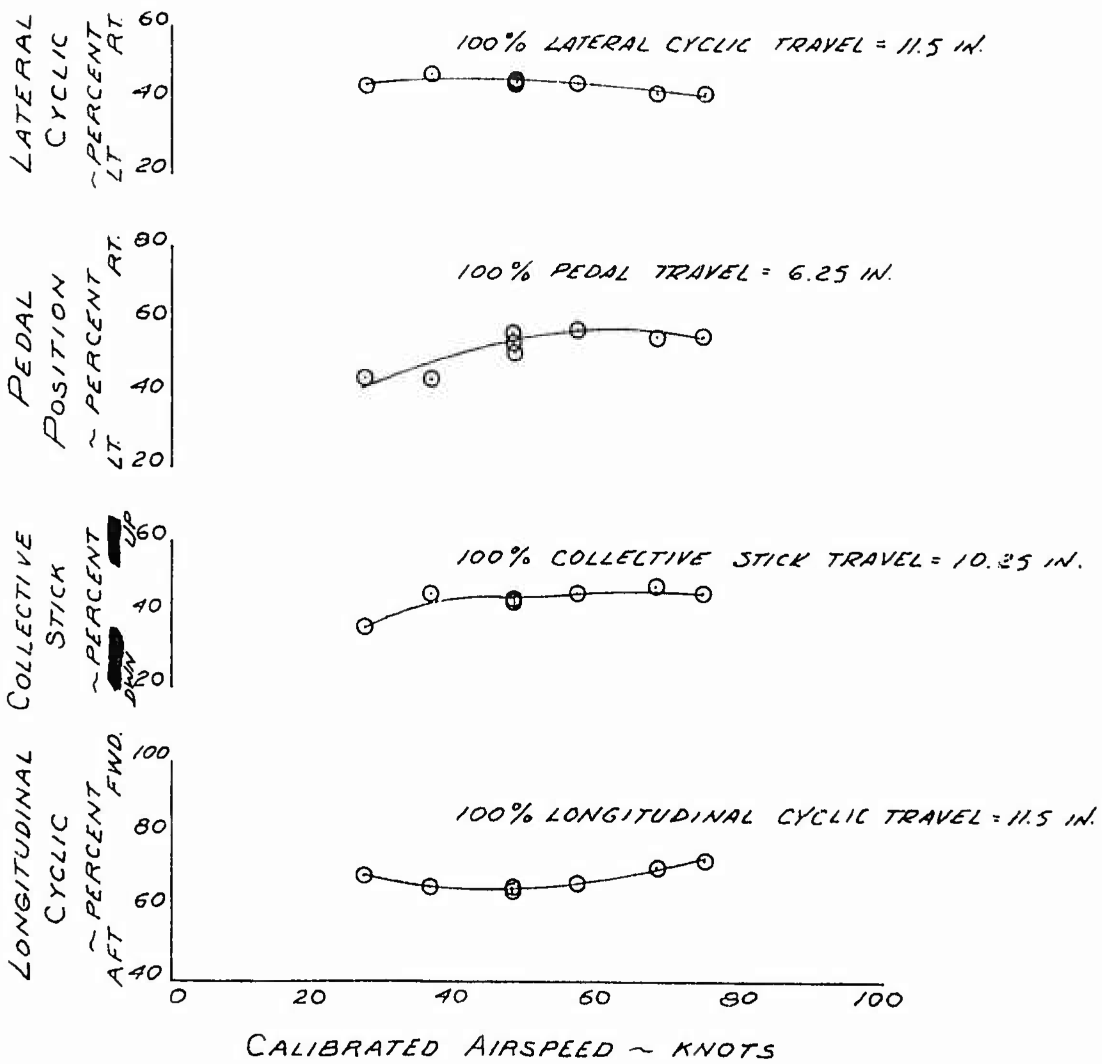

FIGURE No. 38
LONGITUDINAL RESPONSE
MODEL 211 S/N 6256N
SCAS ON
HUEY TUG

SYM.	AVG. GROSS WT.	AVG C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
O	7870 LBS	132.95 IN	5135 FT.	297 RPM

FLIGHT CONDITION -
- LEVEL FLIGHT
O 116 KCAS
CONFIGURATION -
- CLEAN, DOORS CLOSED

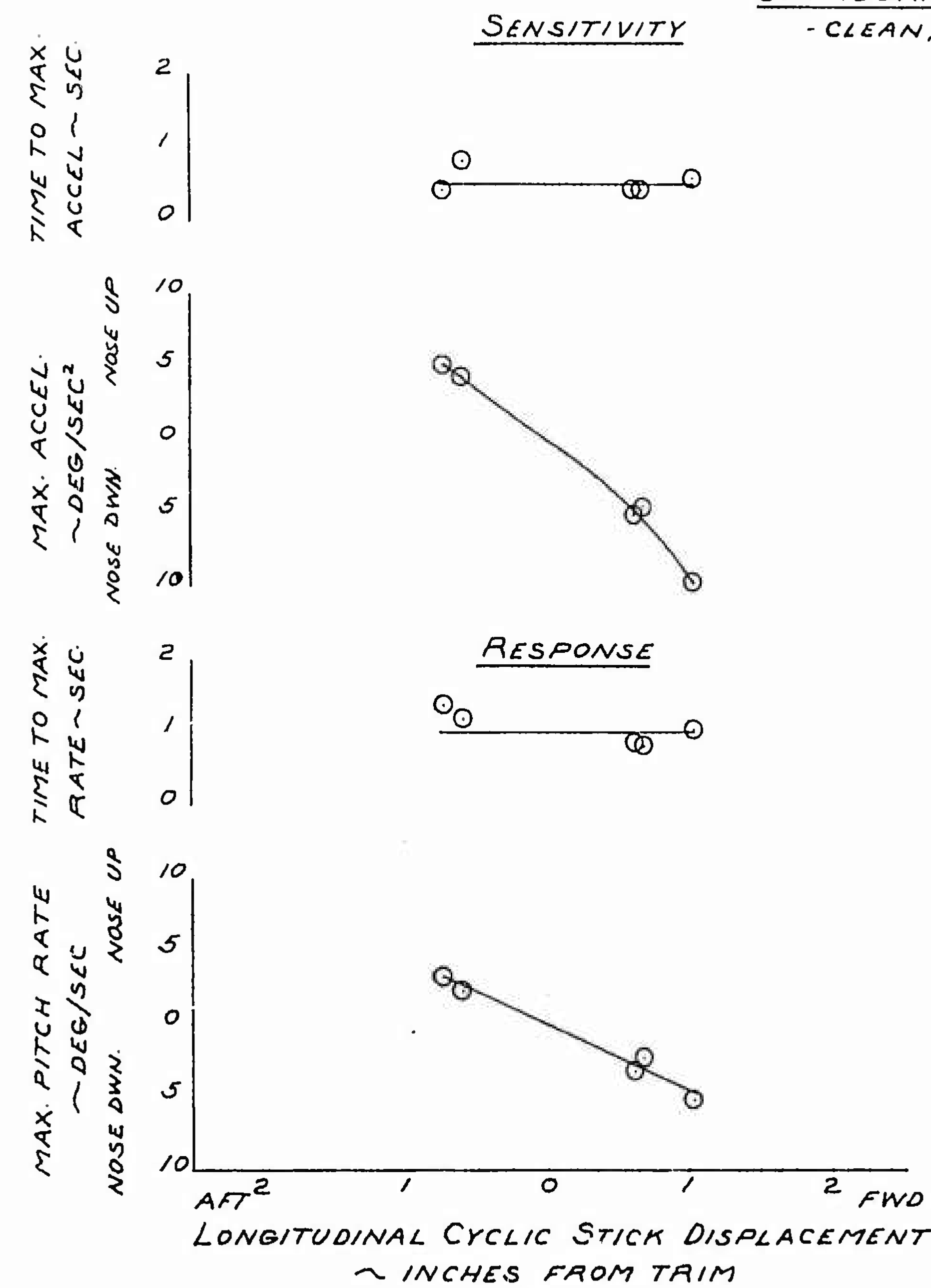

FIGURE No. 39
LONGITUDINAL RESPONSE
MODEL 211 S/N 6256N
SCAS OFF
HUEY TUG

SYM.	AVG. GROSS WT.	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
O	10350 LBS.	129.74 IN	2660 FT.	298 RPM

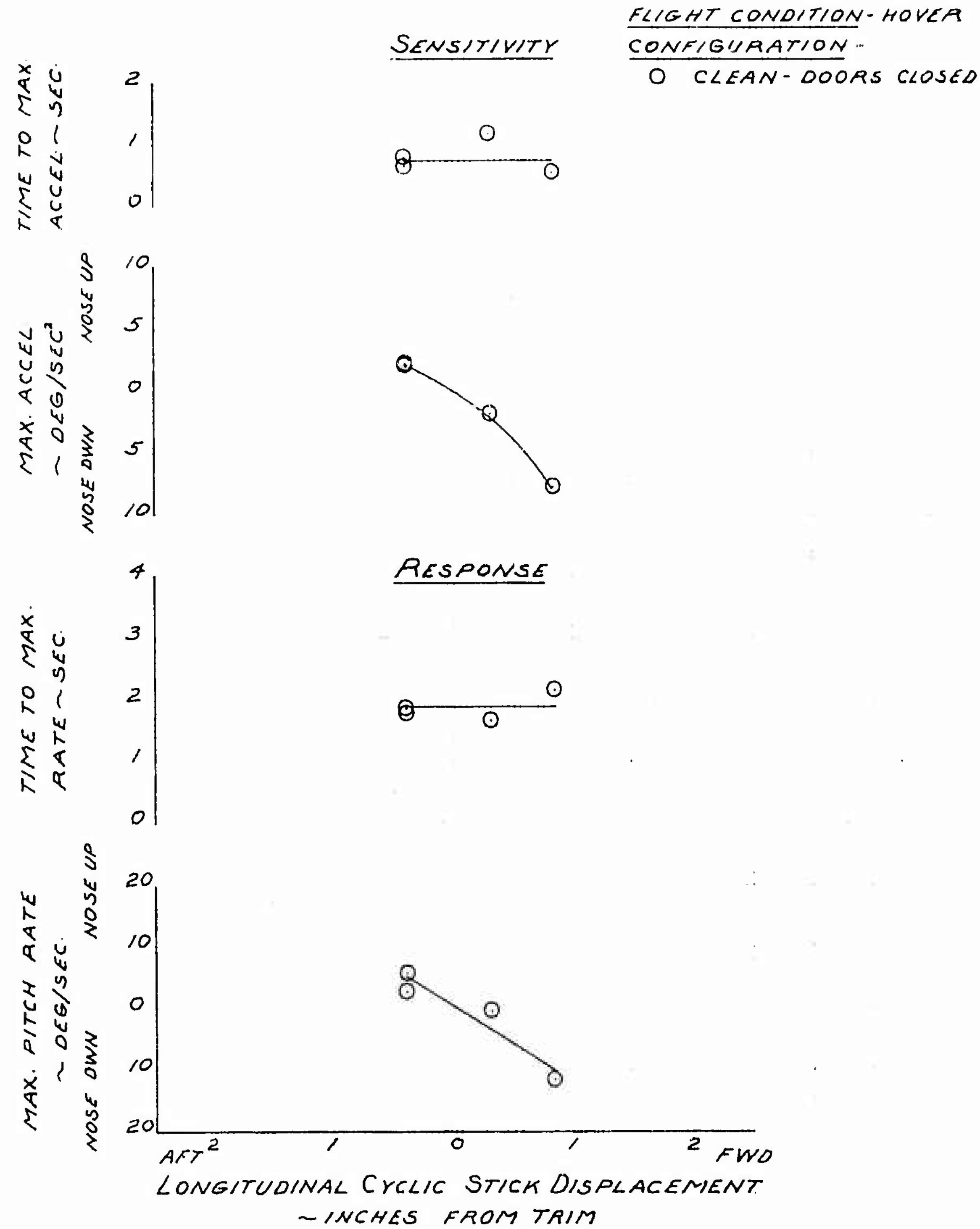

FIGURE No. 40
LONGITUDINAL RESPONSE
MODEL 211 S/N 6256N
SCAS ON
HUEY TUG

SYM	AVG GROSS WT	AVG C.G. STATION	AVG DENSITY ALT.	ROTOR SPEED
O	10485 LBS	129.82 IN	2660 FT	295 RPM

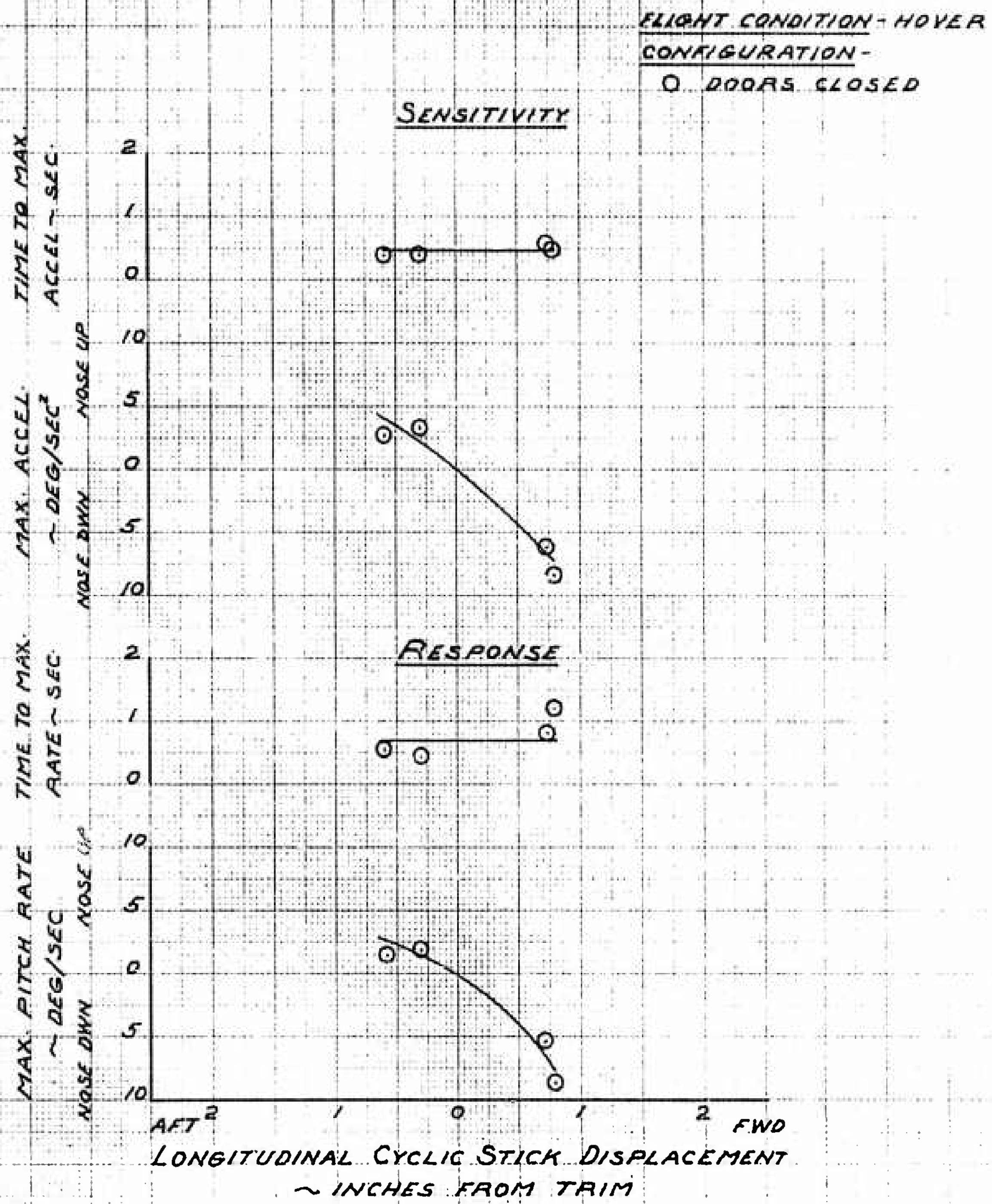

FIGURE No. 41
LONGITUDINAL RESPONSE
MODEL 211 S/N 6256N
SCAS ON
HUEY TUG

SYM	AVG. GROSS WT	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
O	12465 LBS	130.03 IN	2590 FT.	299 RPM

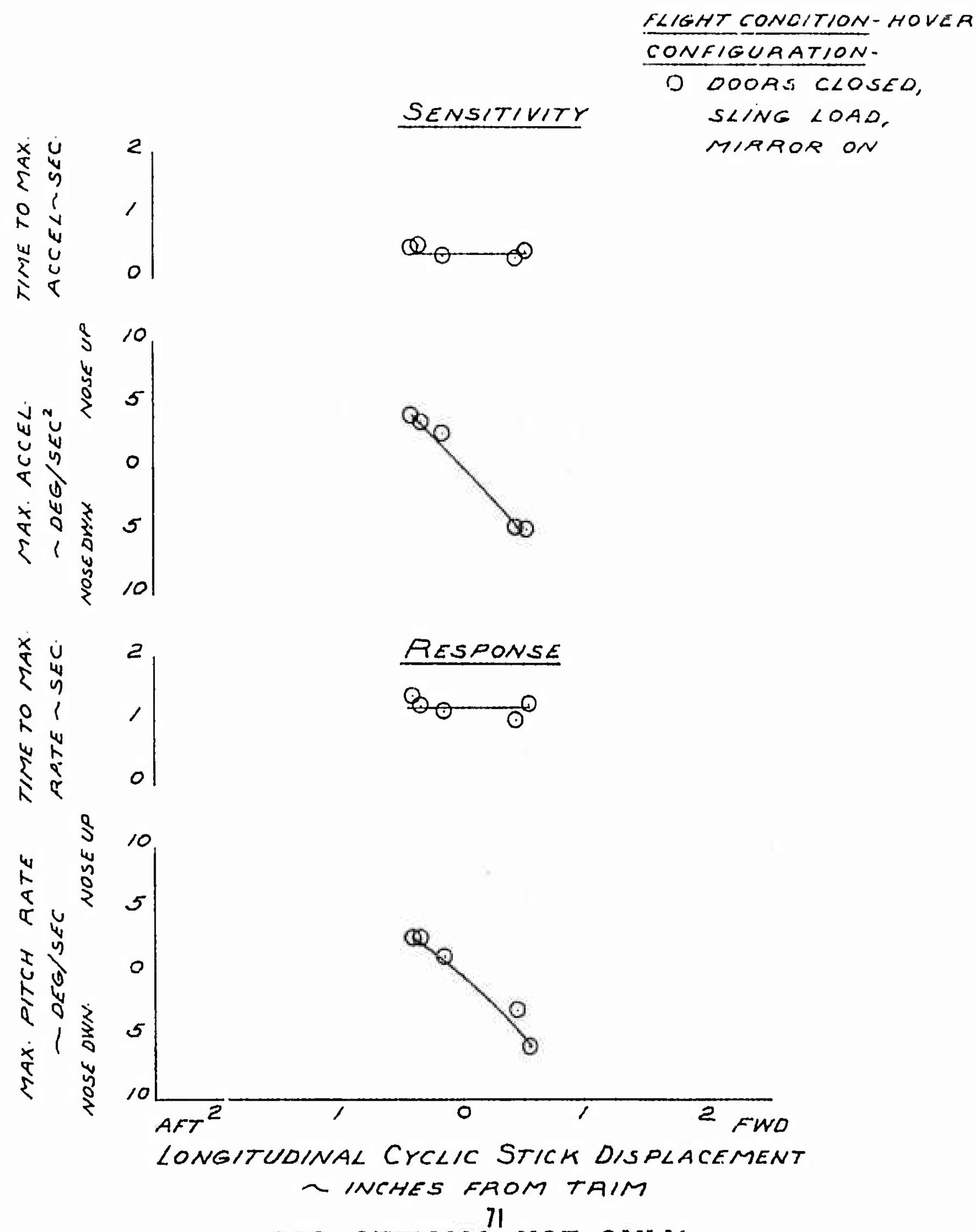

FIGURE No.42
LONGITUDINAL RESPONSE
MODEL 211 S/N N6256N
SCAS ON
HUEY TUG

SYM.	AVG. GROSS WT.	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
O	10485 LBS.	129.82 IN.	2660 FT.	295 RPM
Δ	12465 LBS.	130.03 IN.	2590 FT.	299 RPM

FLIGHT CONDITION - HOVER
CONFIGURATION -
O CLEAN, DOORS CLOSED
Δ DOORS CLOSED MIRROR ON SLING LOAD

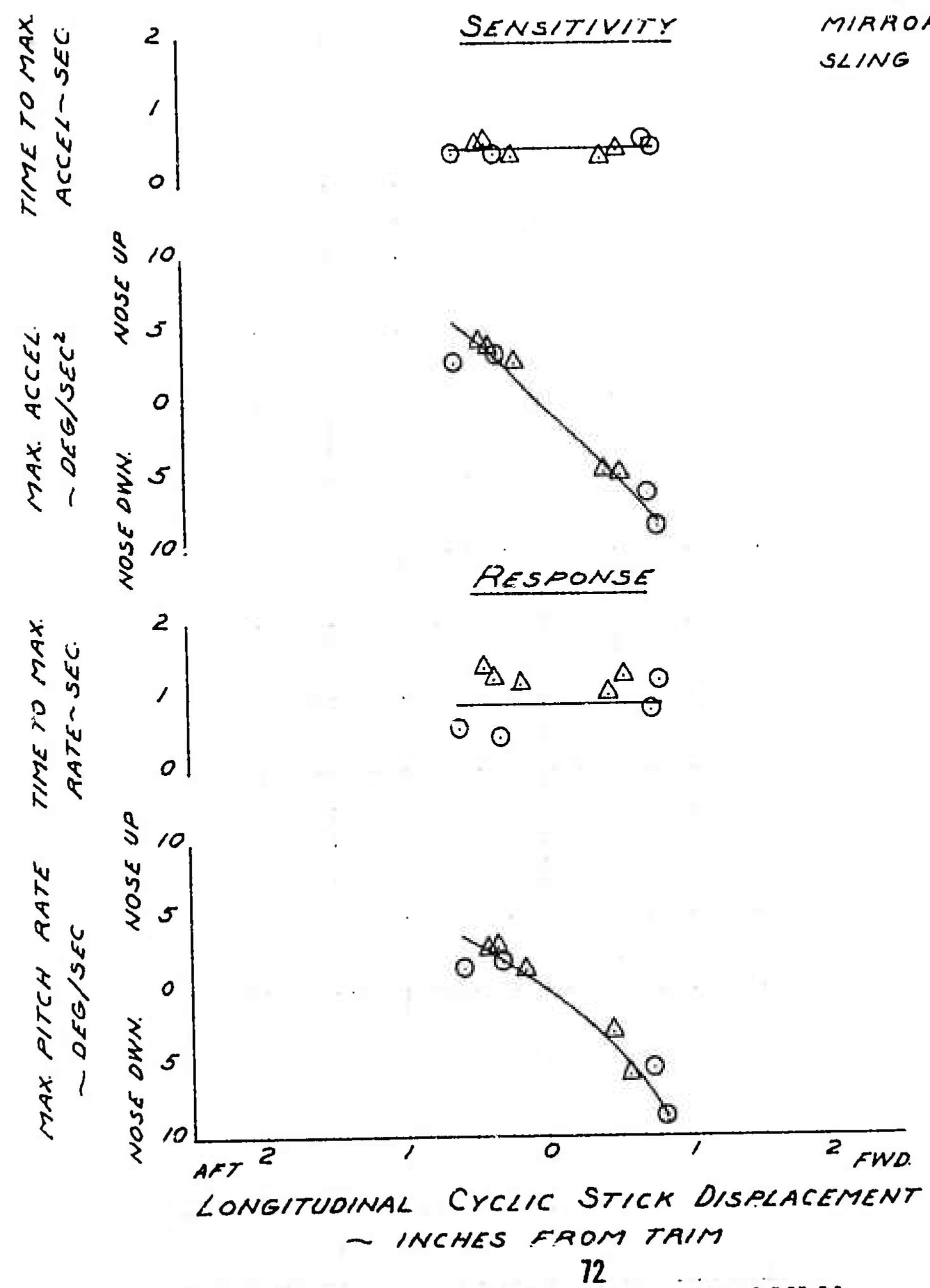

FIGURE No. 43
LATERAL RESPONSE
MODEL 211 S/N 6256N
SCAS ON
HUEY TUG

SYM.	AVG. GROSS WT.	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
O	7785 LBS.	132.93 IN	5155 FT.	297 RPM

FLIGHT CONDITION -
- LEVEL FLIGHT
116 KCAS
CONFIGURATION -
- CLEAN, DOORS CLOSED

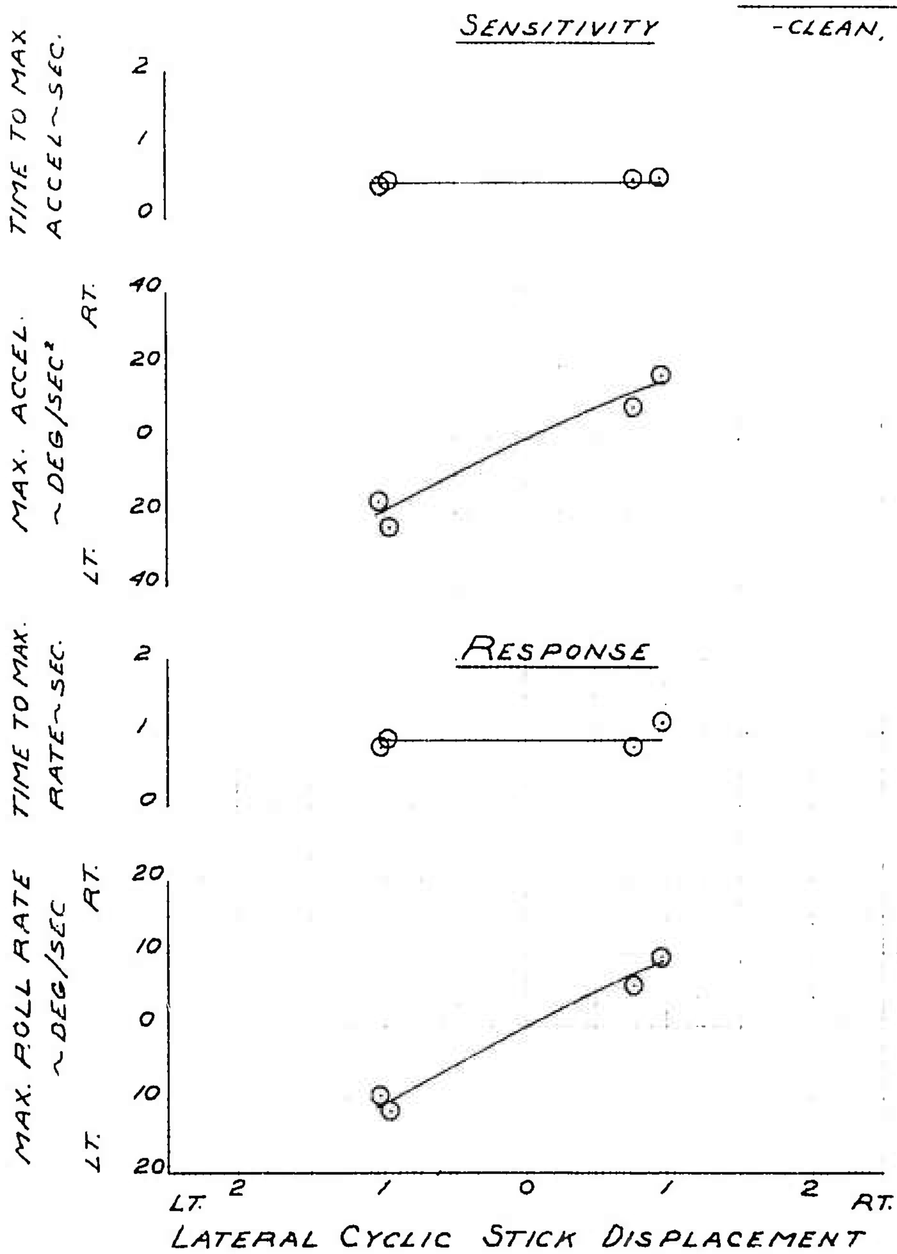

FIGURE No. 44
LATERAL RESPONSE
MODEL 211 S/N 6256N
SCAS OFF
HUEY TUG

SYM.	AVG. GROSS WT.	AVG C.G STATION	AVG. DENSITY ALT.	ROTOR SPEED
O	10305 LBS.	129.71 IN	2660 FT	298 RPM

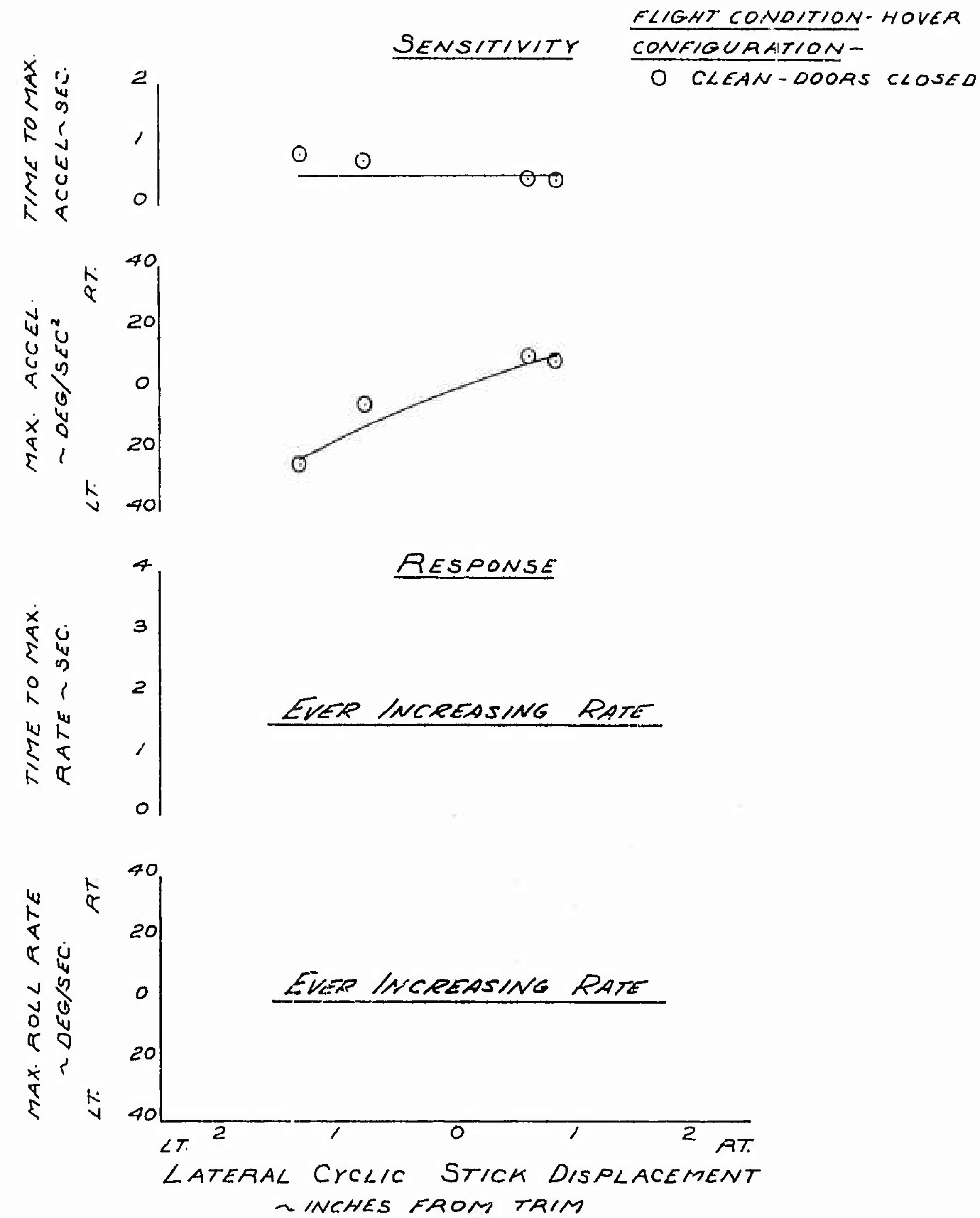

FIGURE No. 45
LATERAL RESPONSE
MODEL 211 S/N 6256N
SCAS ON
HUEY TUG

SYM	AVG. GROSS WT	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
O	10485 LBS	129.82 IN	2660 FT.	295 RPM

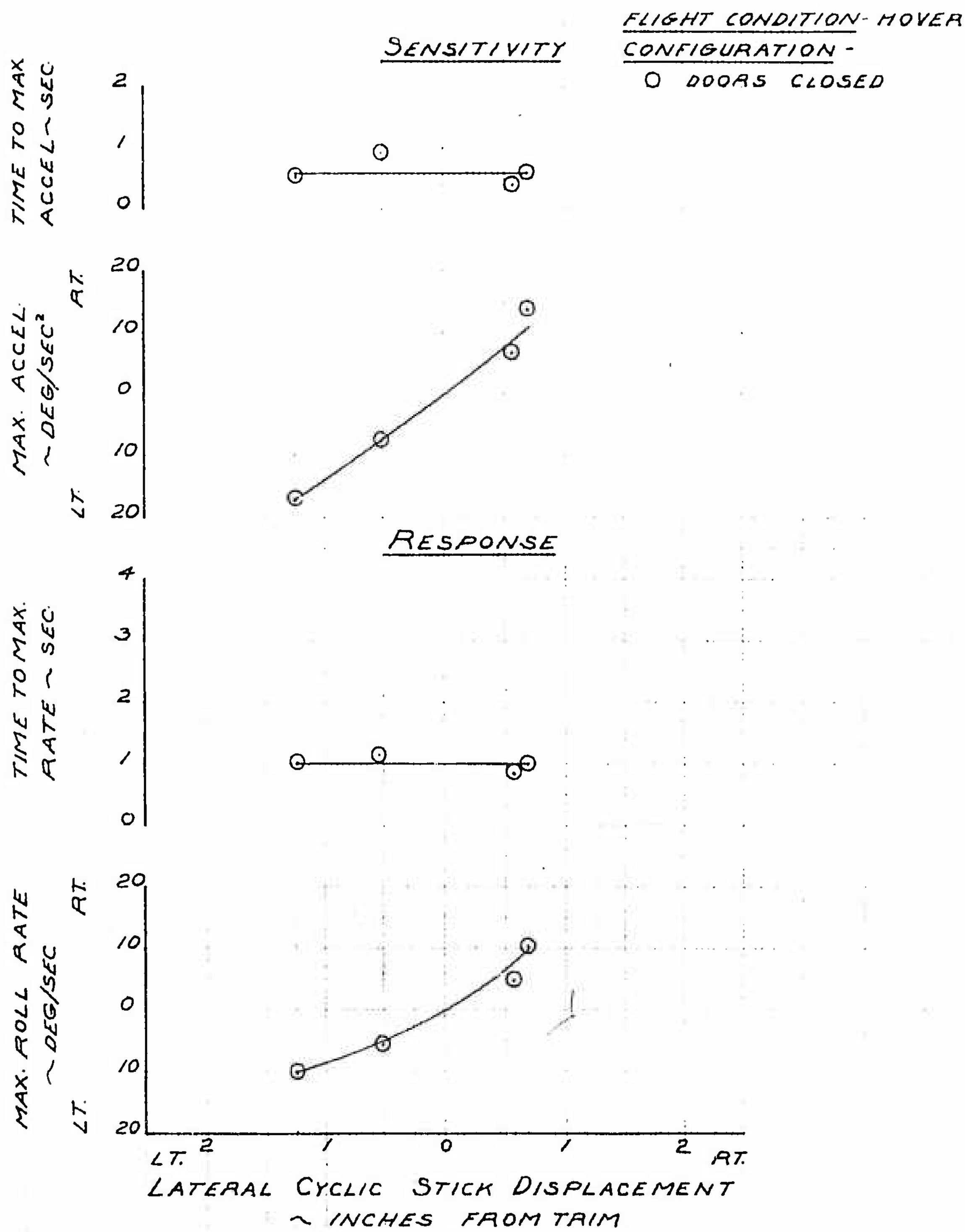

FIGURE No. 46
LATERAL RESPONSE
MODEL 211 S/N 6256N
SCAS ON
HUEY TUG

SYM.	AVG. GROSS WT.	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
O	12465 LBS	130.03 IN	2590 FT.	299 RPM

FLIGHT CONDITION - HOVER
CONFIGURATION -
O DOORS CLOSED, SLING LOAD, MIRROR ON

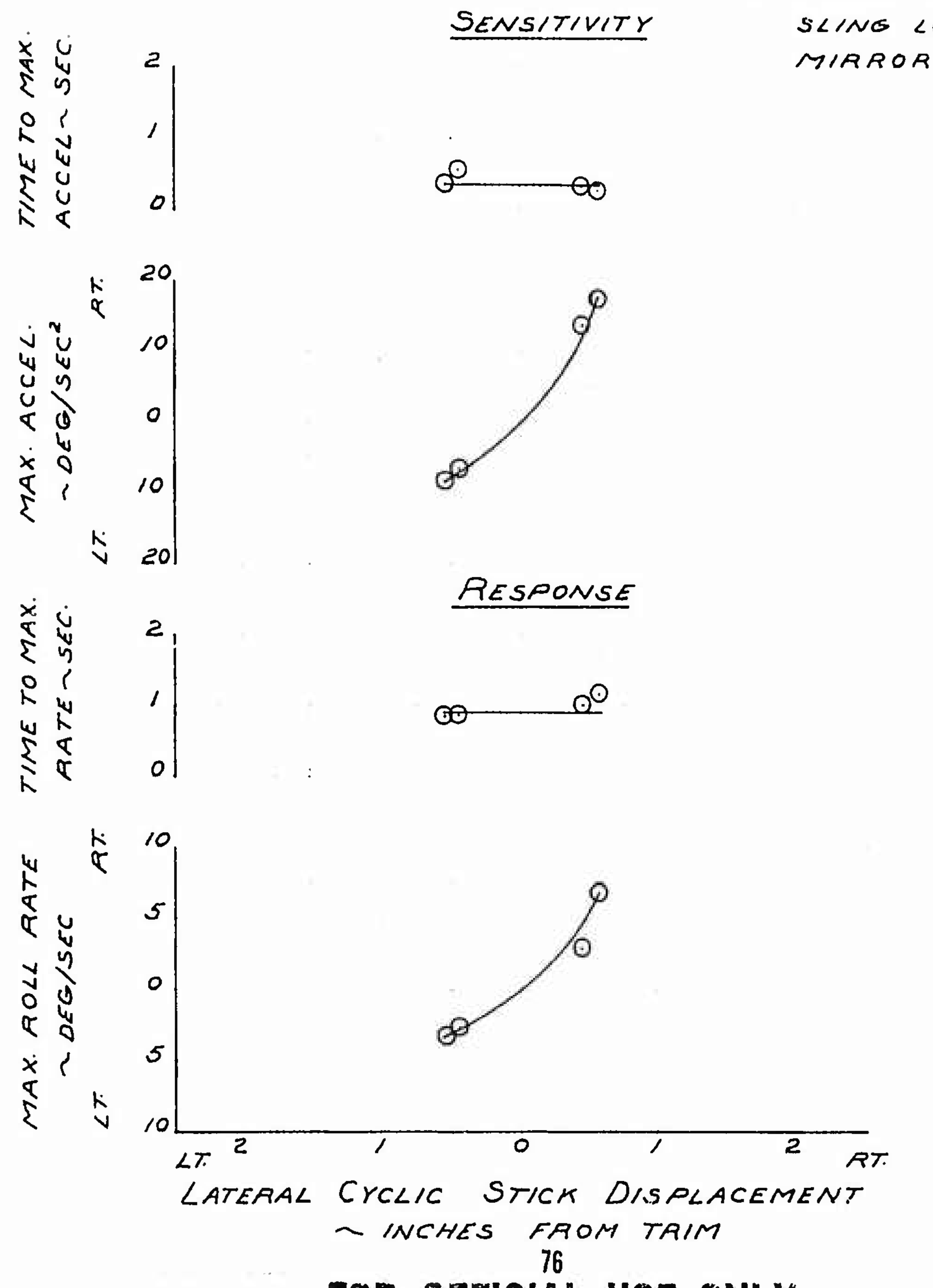

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FIGURE No. 47
LATERAL RESPONSE
MODEL 211 S/N N6256N
SCAS ON
HUEY TUG

SYM.	AVG. GROSS WT.	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
O	10485 LBS.	129.82 IN.	2660 FT.	295 RPM
Δ	12465 LBS.	130.03 IN.	2590 FT.	299 RPM

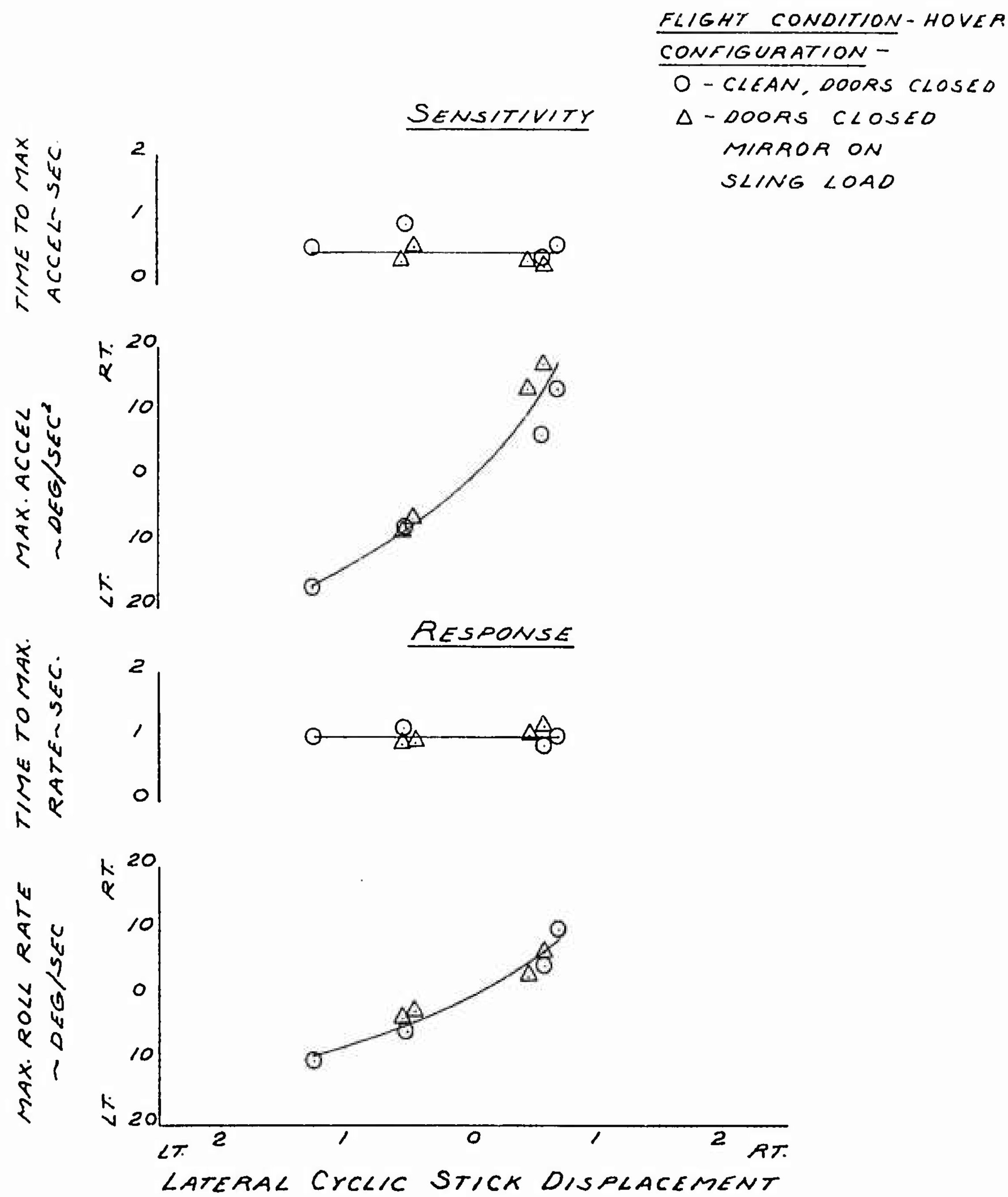

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FIGURE No. 48
DIRECTIONAL RESPONSE
MODEL 211 S/N N6256N

HUEY TUG

SCAS	SYM.	AVG. GROSS WT.	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
ON	⊙	7725 LBS.	132.91 IN.	5155 FT.	297 RPM
OFF	⊡	7775 LBS.	132.92 IN.	6400 FT.	297 RPM
ON	△	12995 LBS.	132.78 IN.	5480 FT.	298 RPM

FLIGHT CONDITION –
– LEVEL FLIGHT
⊙ 116 KCAS
⊡ 75 KCAS
△ 75 KCAS
CONFIGURATION –
⊙ CLEAN, DOORS CLOSED
⊡ DOORS OPEN, MIRROR ON
△ DOORS OPEN, MIRROR ON, SLING LOAD

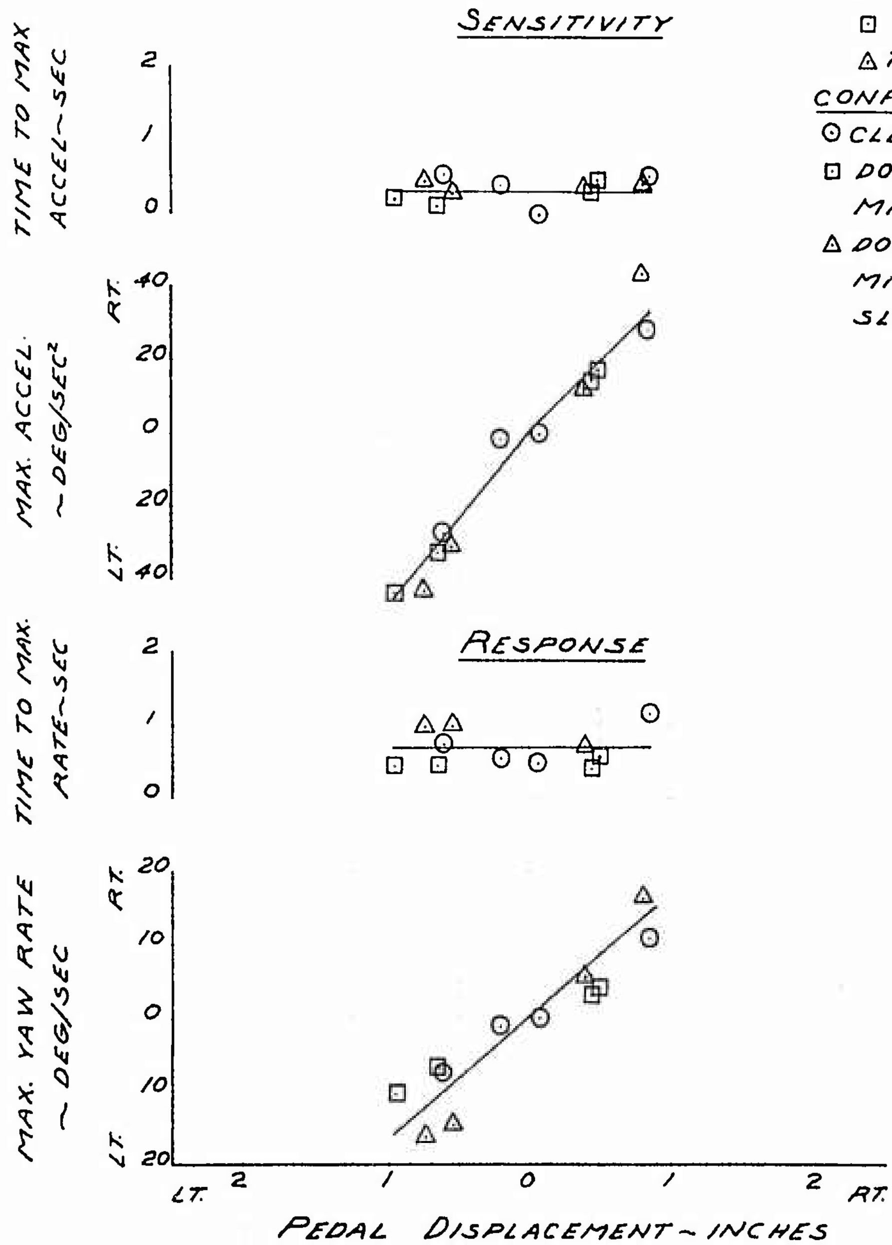

FIGURE NO. 49
DIRECTIONAL RESPONSE
MODEL 211 S/N 6256 N
SCAS ON
HUEY TUG

SYM.	AVG. GROSS WT.	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
○	7725 LBS.	132.91 IN.	5155 FT.	297

FLIGHT CONDITION -
- LEVEL FLIGHT
@ 116 KCAS
CONFIGURATION -
- CLEAN, DOORS CLOSED

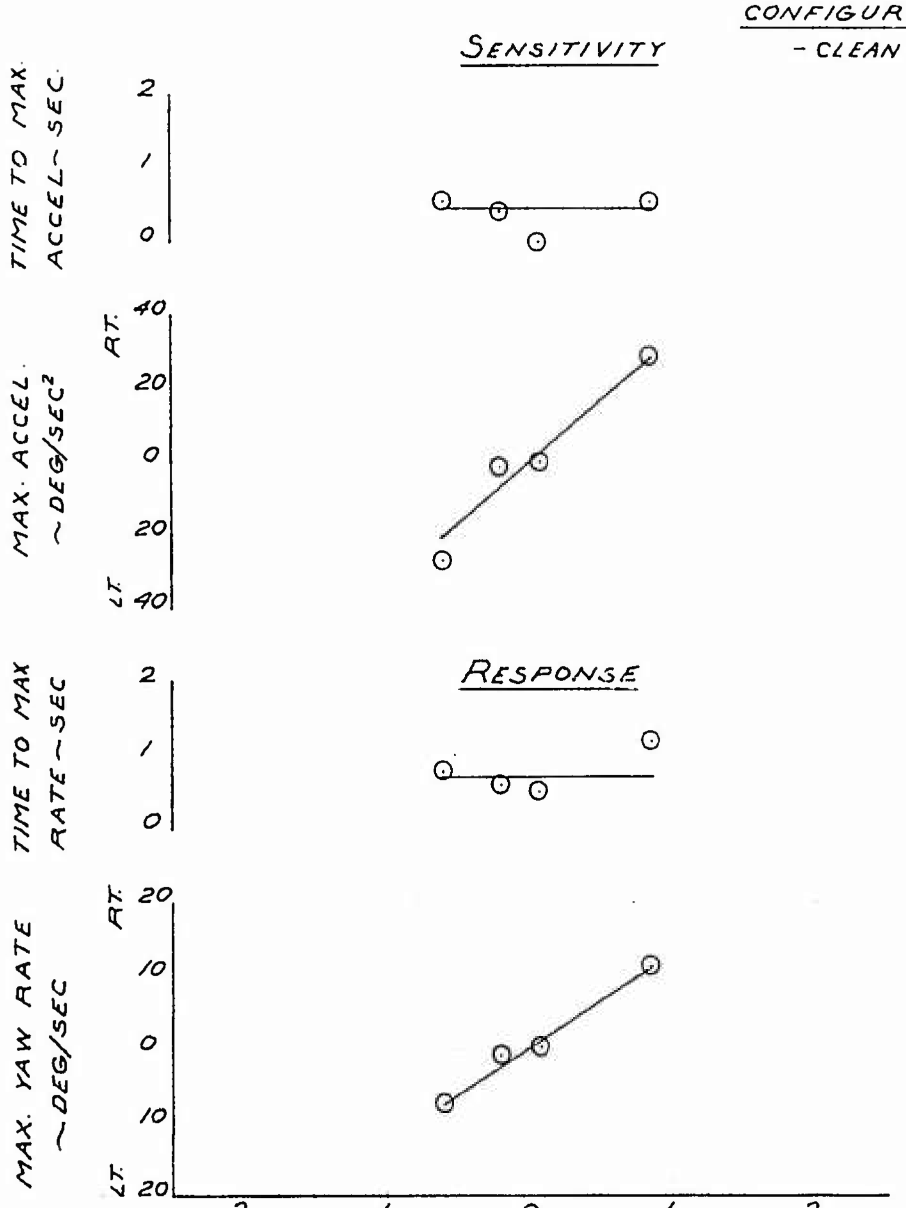

FIGURE No. 50
DIRECTIONAL RESPONSE
MODEL 211 S/N 6256N
SCAS OFF
HUEY TUG

SYM	AVG. GROSS WT.	AVG C.G STATION	AVG. DENSITY ALT.	ROTOR SPEED
O	10250 LBS.	129.68 IN	2660 FT.	297 RPM

FLIGHT CONDITION - HOVER
CONFIGURATION -
O DOORS CLOSED

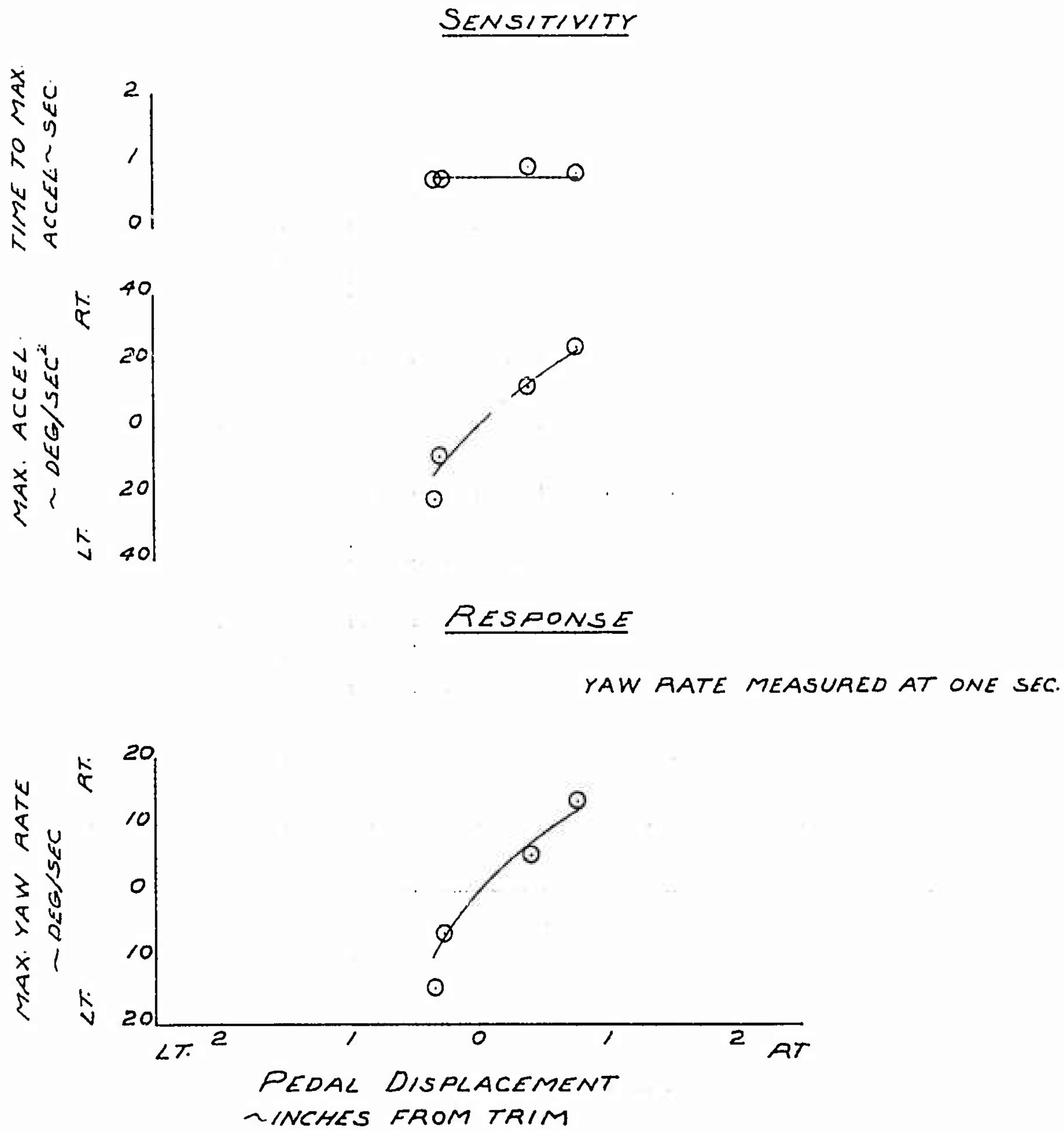

FIGURE NO. 51
DIRECTIONAL RESPONSE
MODEL 211 S/N 6256
SCAS ON
HUEY TUG

SYM.	AVG. GROSS WT.	AVG C.G. STATION	AVE. DENSITY ALT.	ROTOR SPEED
⊙	10,385 LBS.	129.76 IN	2660 FT.	297 RPM

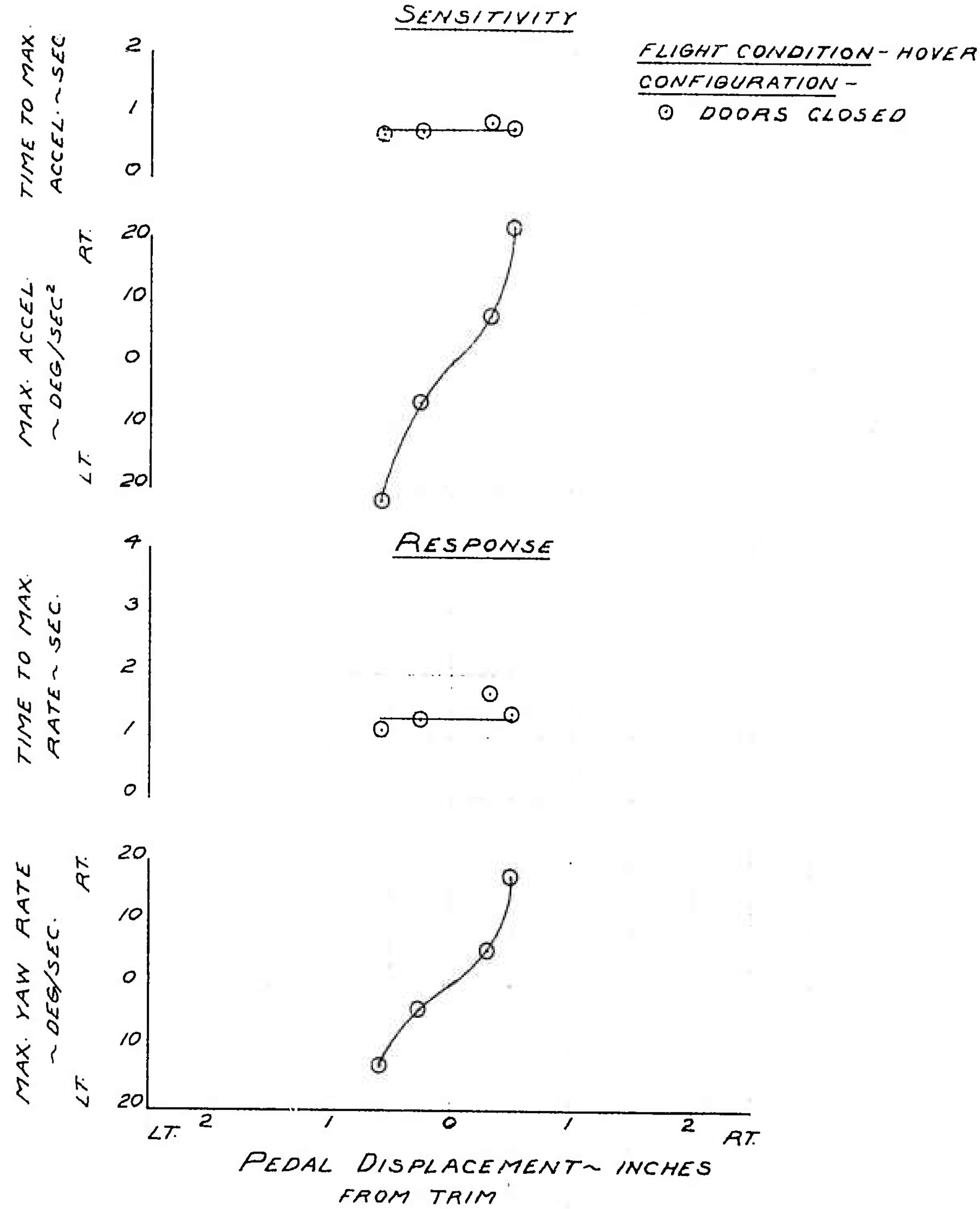

FIGURE NO. 52
DIRECTIONAL RESPONSE
MODEL 211 S/N 6256N
SCAS ON
HUEY TUG

SYM.	AVG. GROSS WT.	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
O	12375 LBS.	129.99 IN.	2590 FT	299 RPM

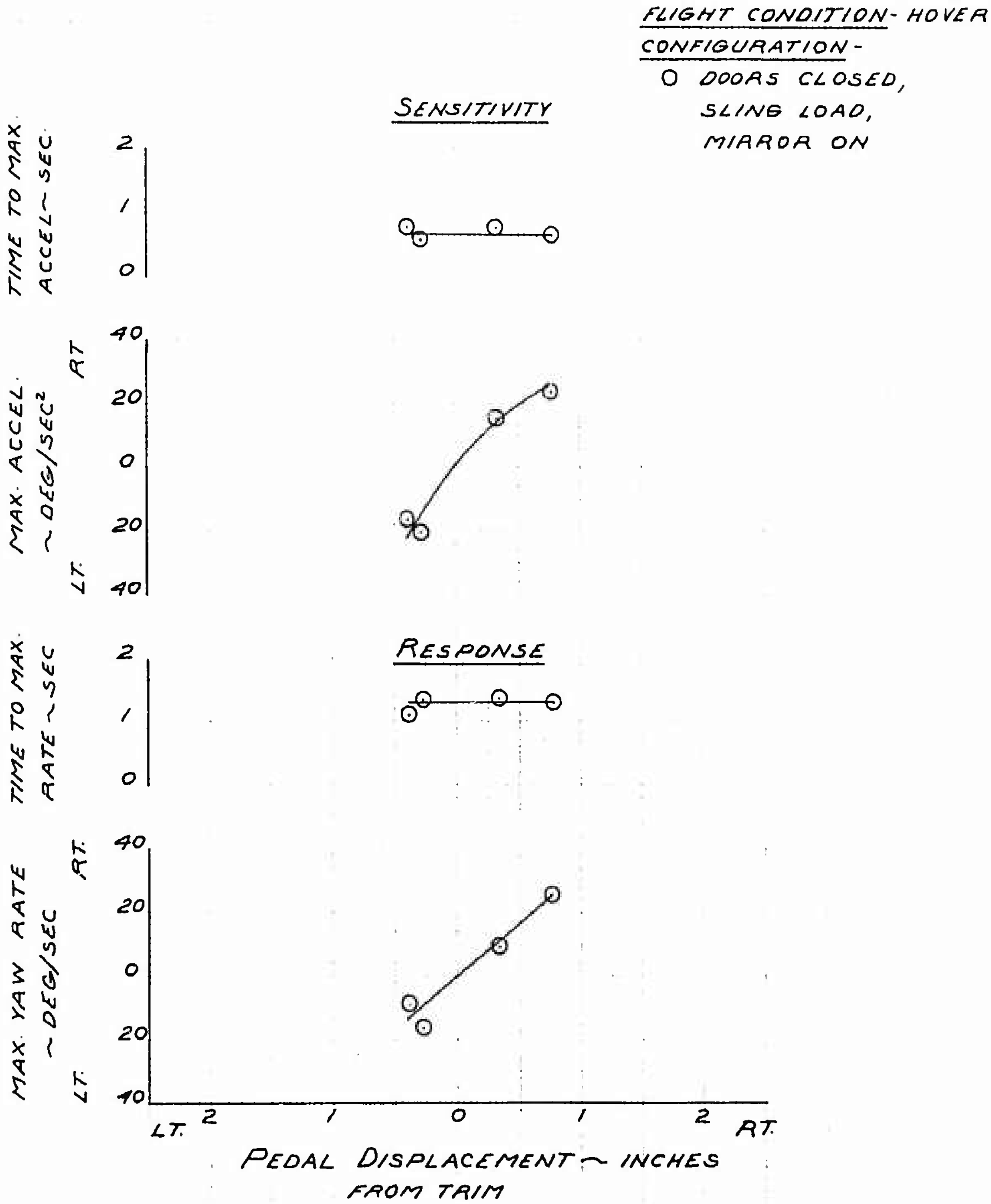

FIGURE No. 53
DIRECTIONAL RESPONSE
MODEL 211 S/N N6256N
SCAS ON
HUEY TUG

SYM.	AVG. GROSS WT.	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
⊙	10 385 LBS.	129.76 IN.	2660 FT.	297 RPM
△	12 375 LBS.	129.99 IN.	2590 FT.	299 RPM

FLIGHT CONDITION - HOVER
CONFIGURATION -
⊙ CLEAN - DOORS CLOSED
△ DOORS CLOSED
MIRROR ON
SLING LOAD

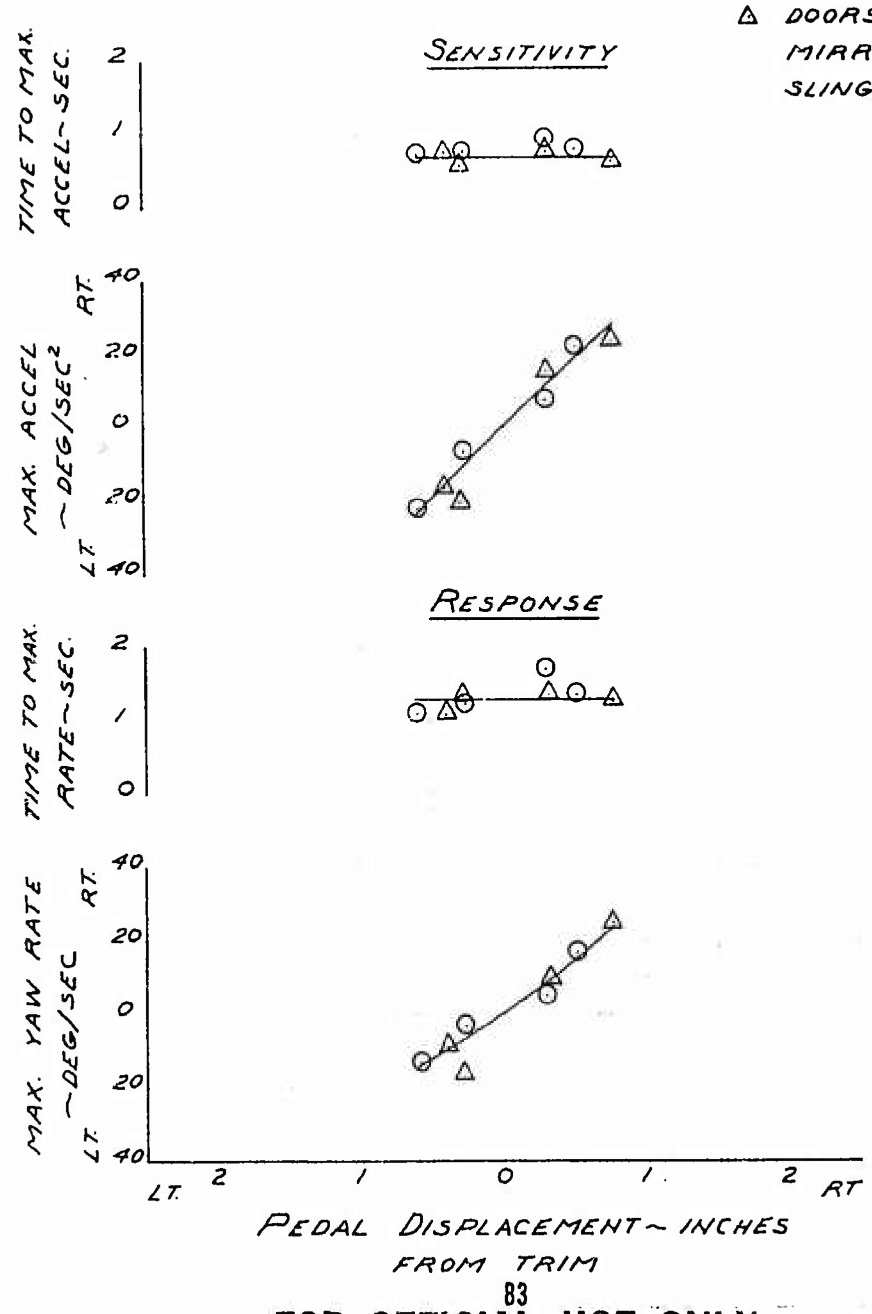

FIGURE No. 54
CONTROL POSITIONS IN SIDEWARD FLIGHT
MODEL 211 S/N N6256N
HUEY TUG

SYM.	AVG. GROSS WT.	AVG. C.G. STATION.	AVG. DENSITY ALT.	ROTOR SPEED
⊙	10775 LBS.	131.94 IN.	9855 FT.	299 RPM
⊡	13230 LBS.	131.97 IN.	4545 FT.	298 RPM
◇	13965 LBS.	131.95 IN.	3745 FT.	299 RPM
△	13100 LBS.	131.68 IN.	1200 FT.	299 RPM

SYM.	CONFIGURATION
⊙, ⊡, ◇, △	DOORS CLOSED, MIRROR ON, SLING LOAD

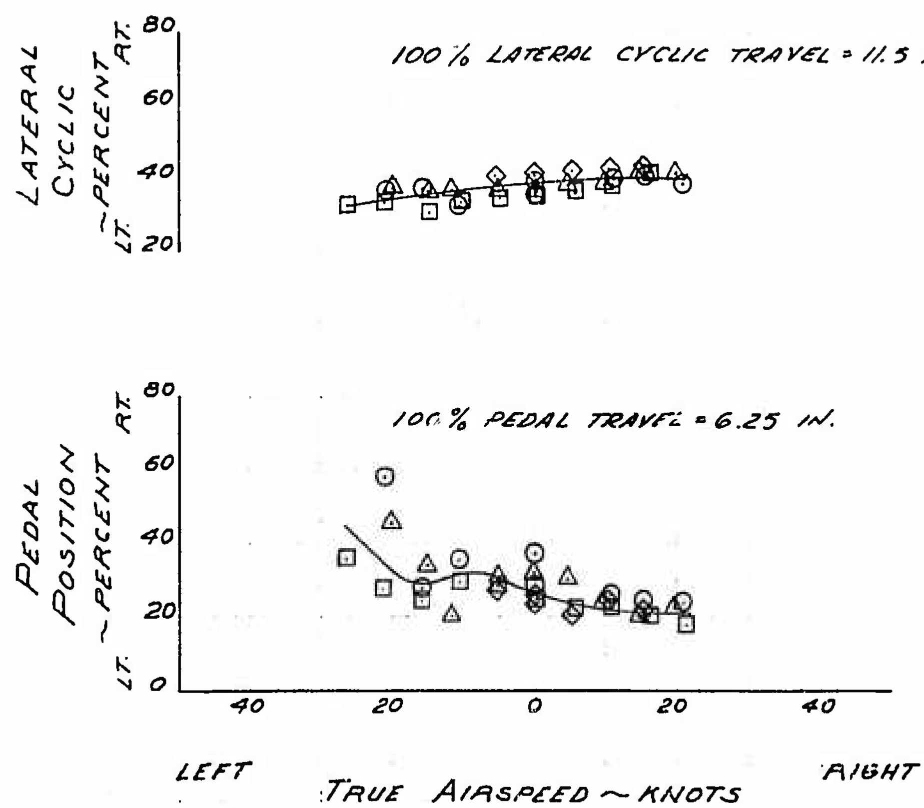

FIGURE NO. 55
CONTROL POSITIONS IN SIDEWARD FLIGHT
MODEL 211 S/N N6256N
HUEY TUG

AVG. GROSS WT.	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
10775 LBS	131.94 IN.	9855 FT	299 RPM

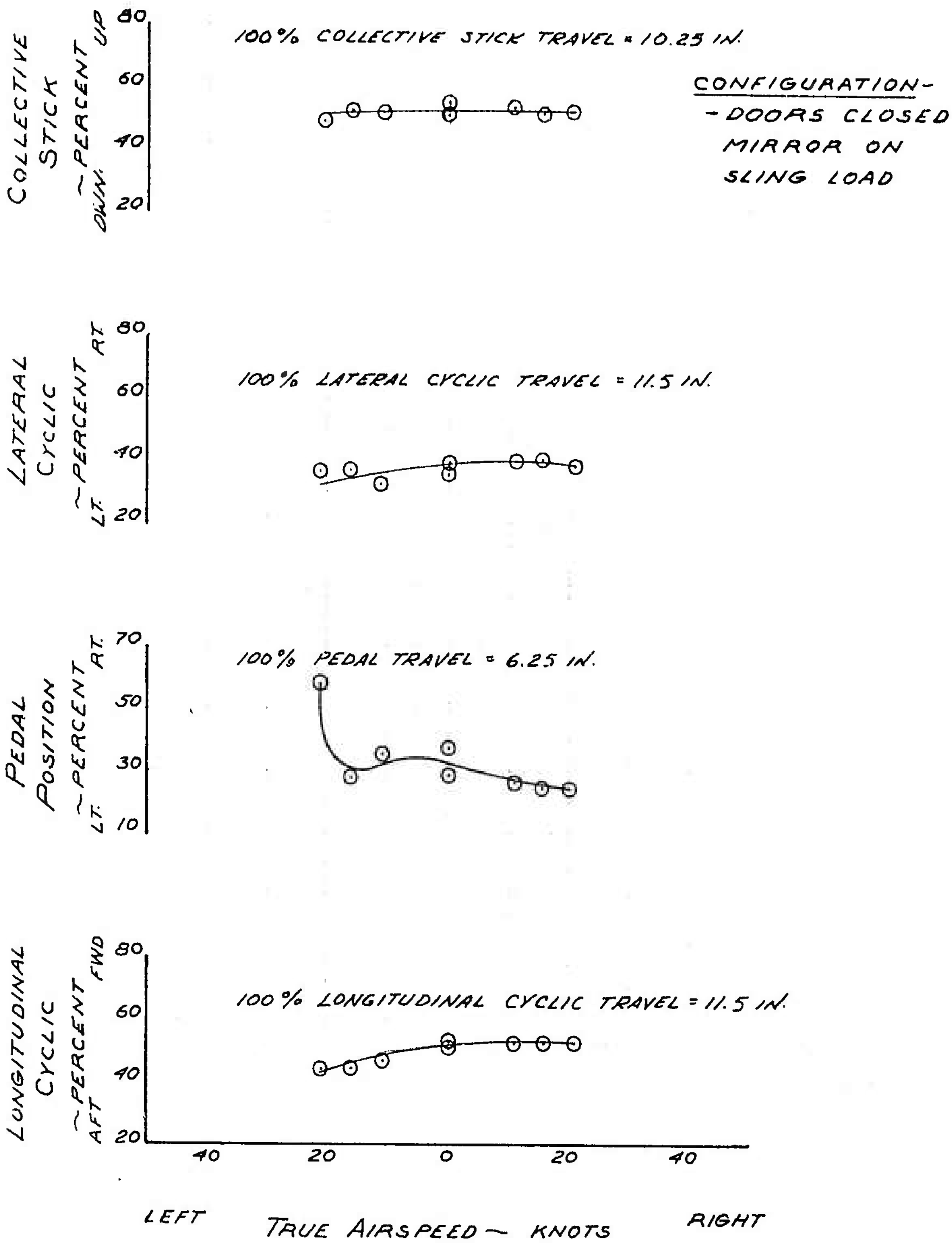

FIGURE NO. 56

CONTROL POSITIONS IN SIDEWARD FLIGHT

MODEL 211 S/N N6256N

HUEY TUG

AVG. GROSS WT.	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
13100 LBS.	131.68 IN	1200 FT.	299 RPM

CONFIGURATION -
- DOORS CLOSED
MIRROR ON
SLING LOAD

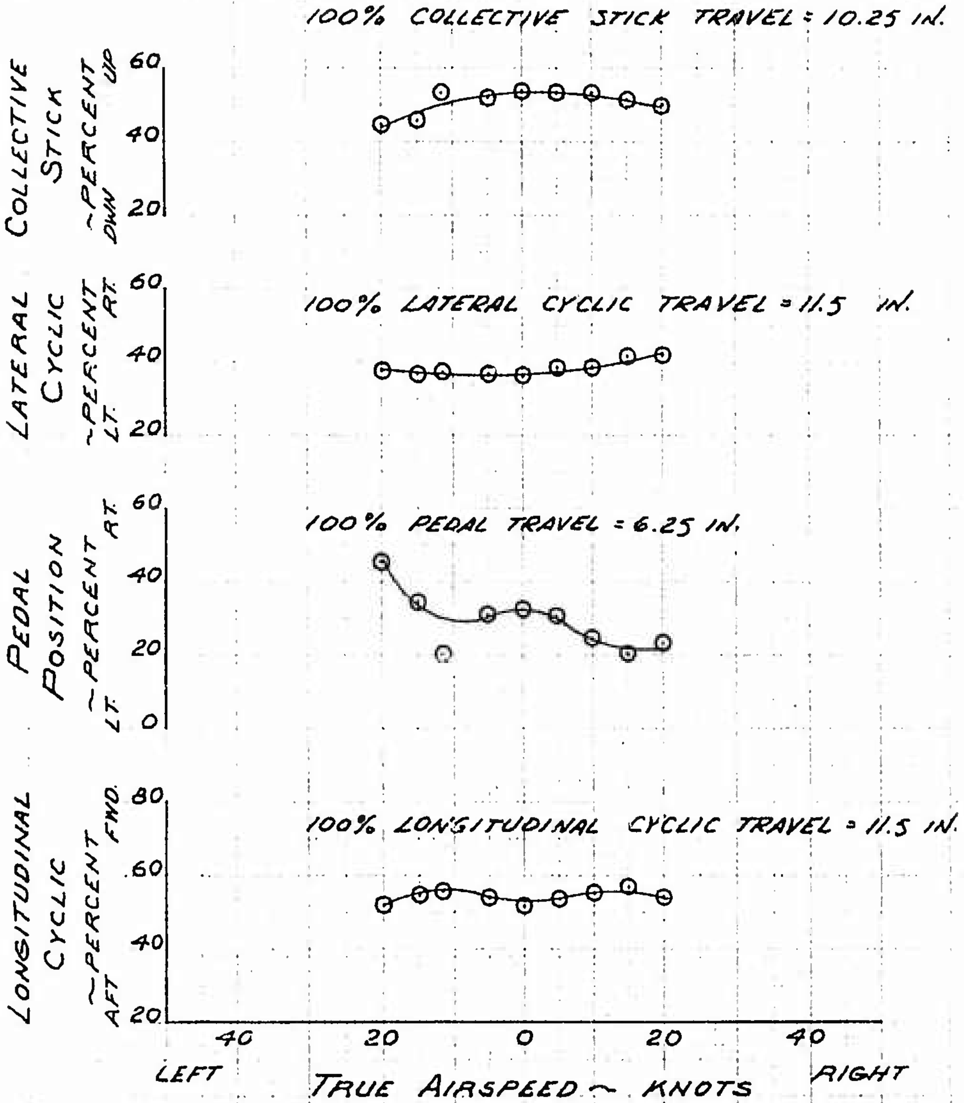

FIGURE No. 57
CONTROL POSITIONS IN SIDEWARD FLIGHT
MODEL 211 S/N N6256N
HUEY TUG

AVG. GROSS WT.	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
13965 LBS.	131.95 IN.	3745 FT.	299 RPM

NOTE: LEFT SIDEWARD FLIGHT LIMITED BY TAIL ROTOR POWER REQUIREMENT

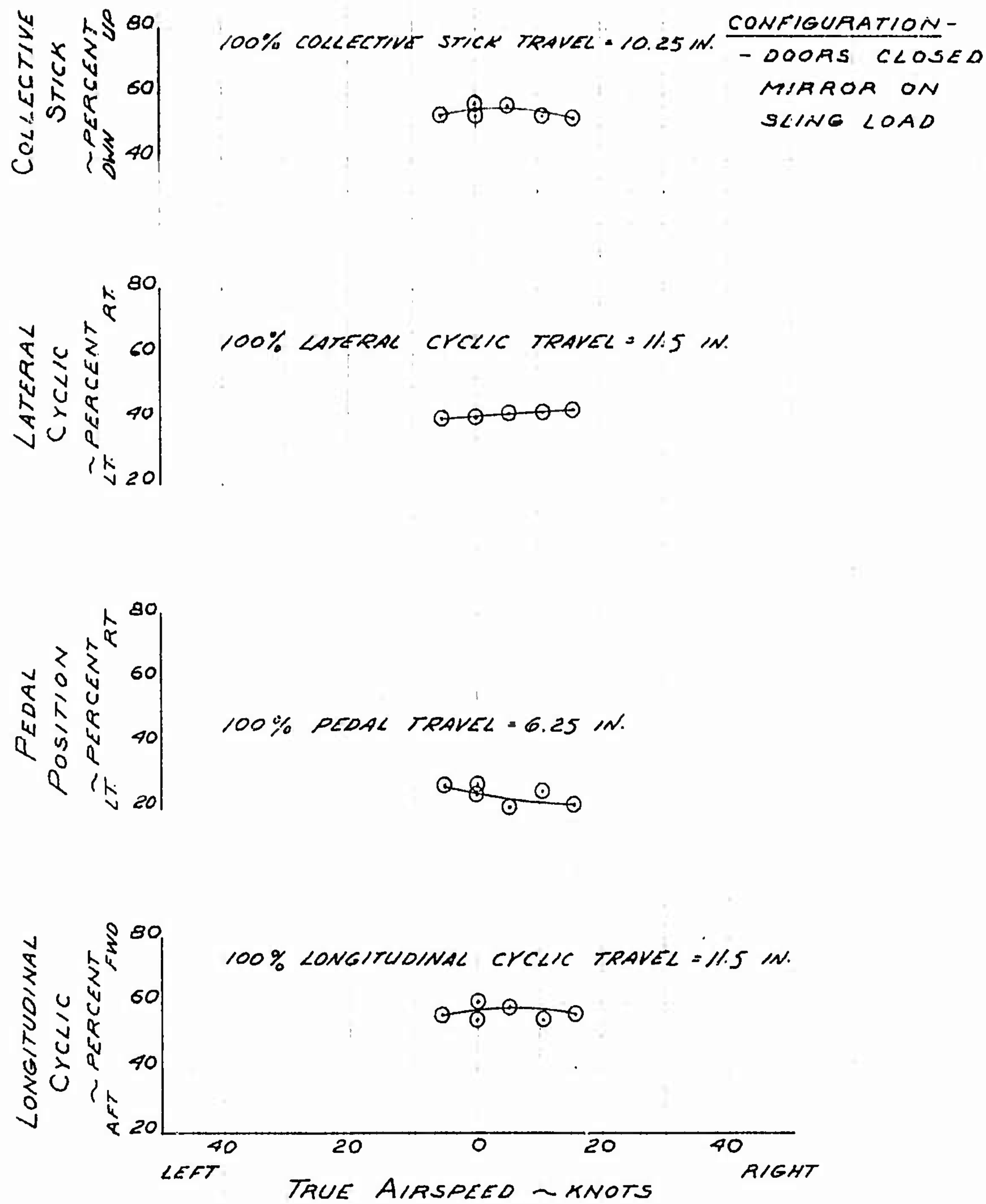

FIGURE No. 58

CONTROL POSITIONS IN SIDEWARD FLIGHT

MODEL 211 S/N N6256N

HUEY TUG

AVG. GROSS WT.	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
13230 LBS.	131.97 IN.	4545 FT.	298 RPM

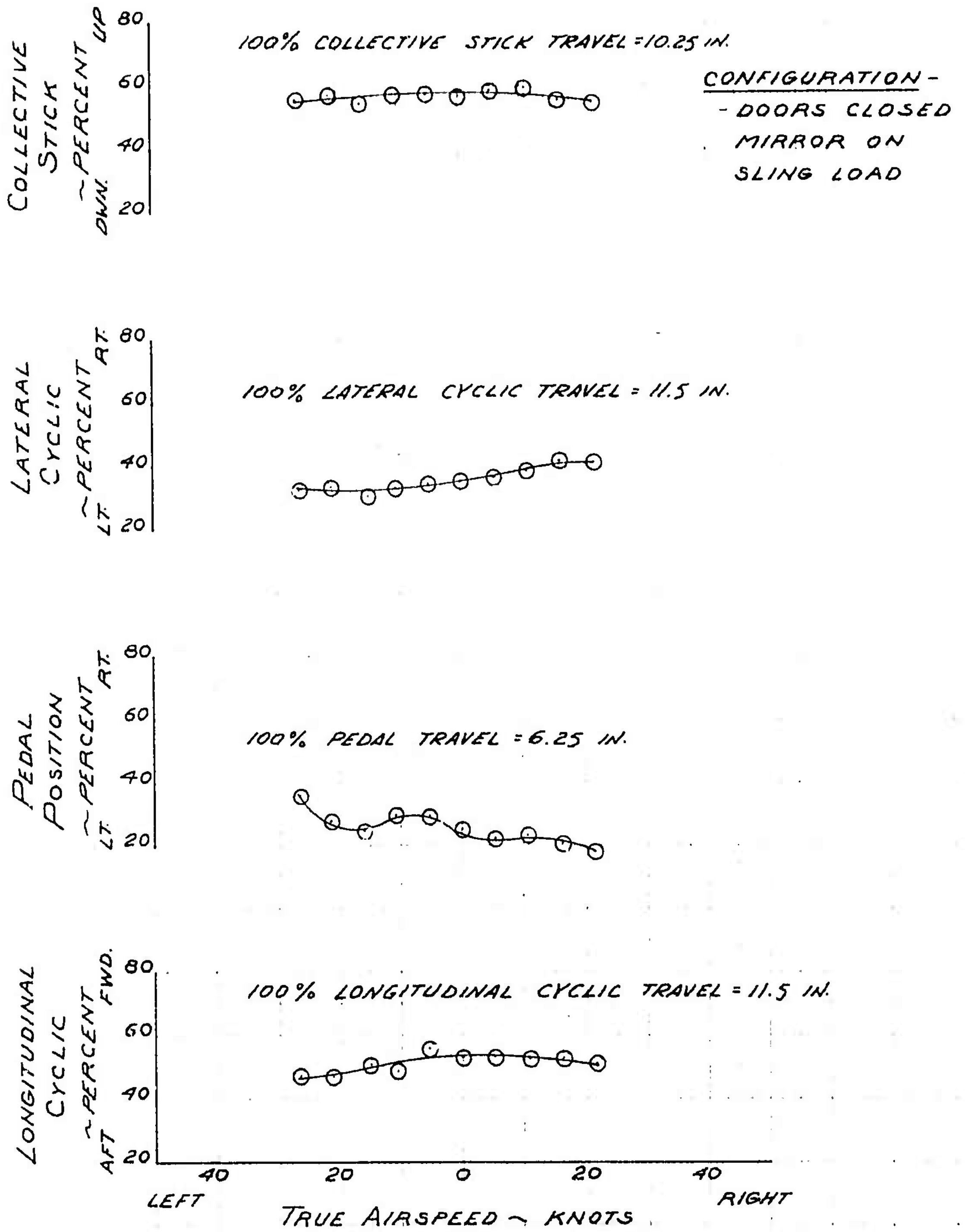

FIGURE NO. 59

CONTROL POSITIONS IN REARWARD FLIGHT

MODEL 211 S/N N6256N

HUEY TUG

AVG. GROSS WT.	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
10715 LBS.	131.91 IN.	9855 FT.	299 RPM

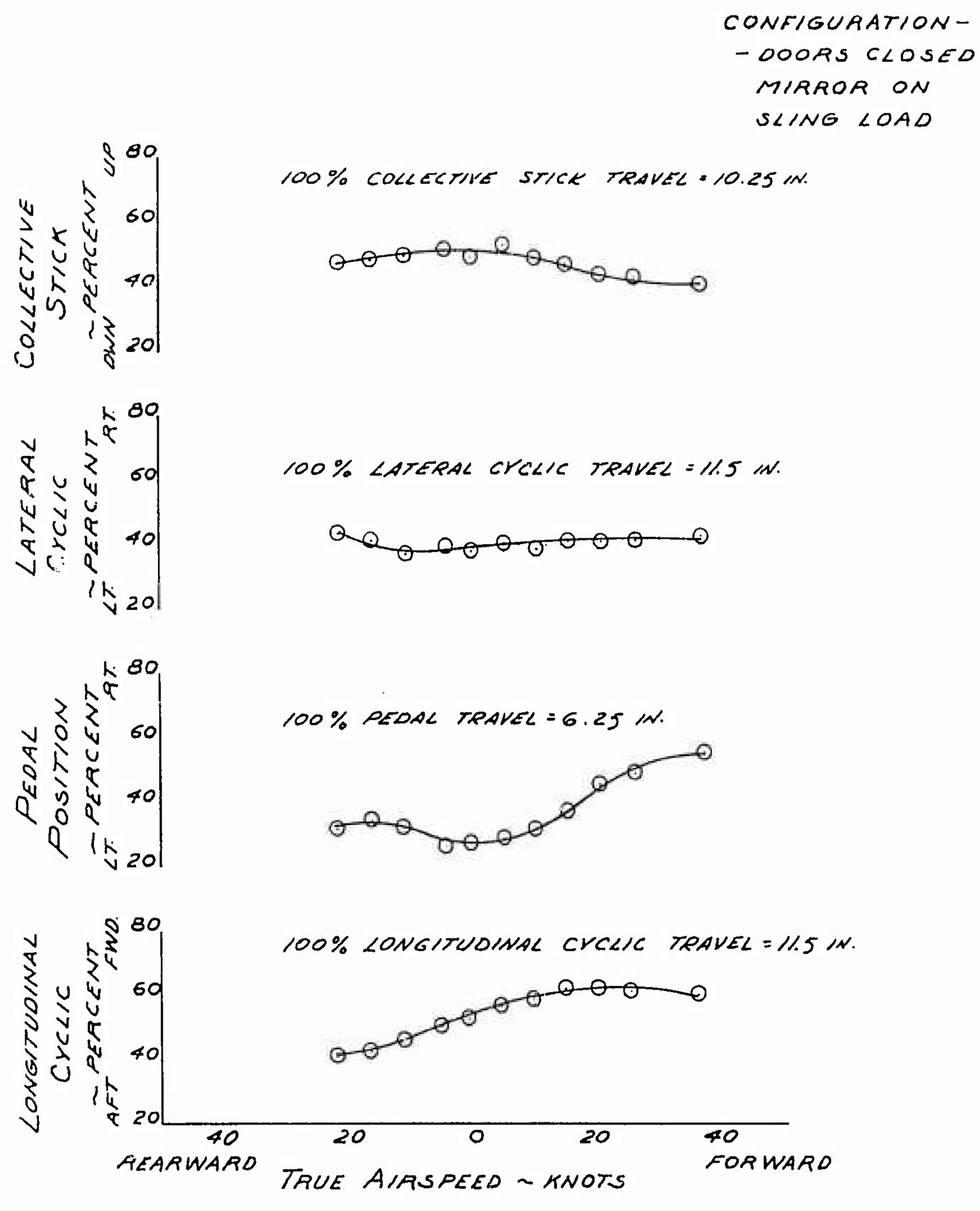

FIGURE No. 60

CONTROL POSITIONS IN REARWARD FLIGHT

MODEL 211 S/N N6256N

HUEY TUG

AVG. GROSS WT	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
13100 LBS.	131.68 IN.	1200 FT.	299 RPM

CONFIGURATION-
- DOORS CLOSED
- MIRROR ON
- SLING LOAD

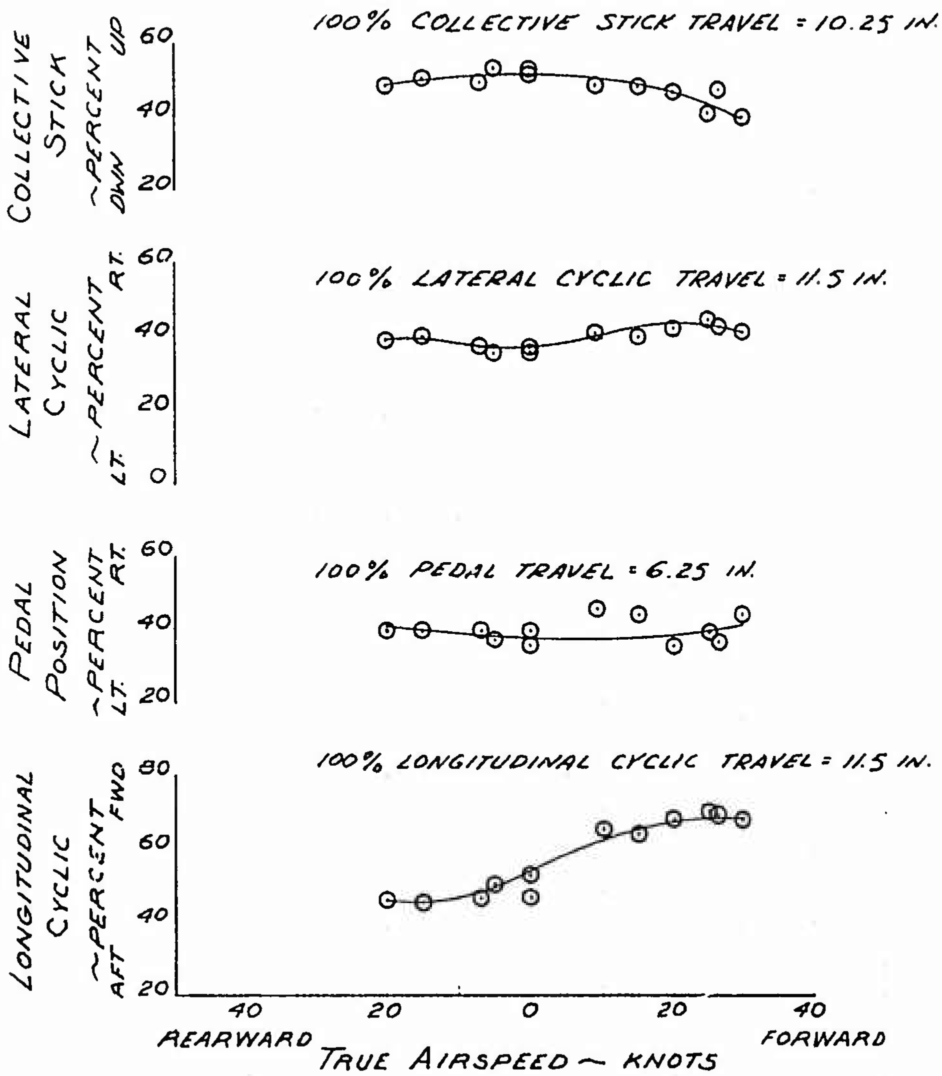

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FIGURE No. 61
CONTROL POSITIONS IN REARWARD FLIGHT
MODEL 211 S/N N6256N
HUEY TUG

AVG. GROSS WT.	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
13965 LBS.	131.95 IN.	3745 FT	301 RPM

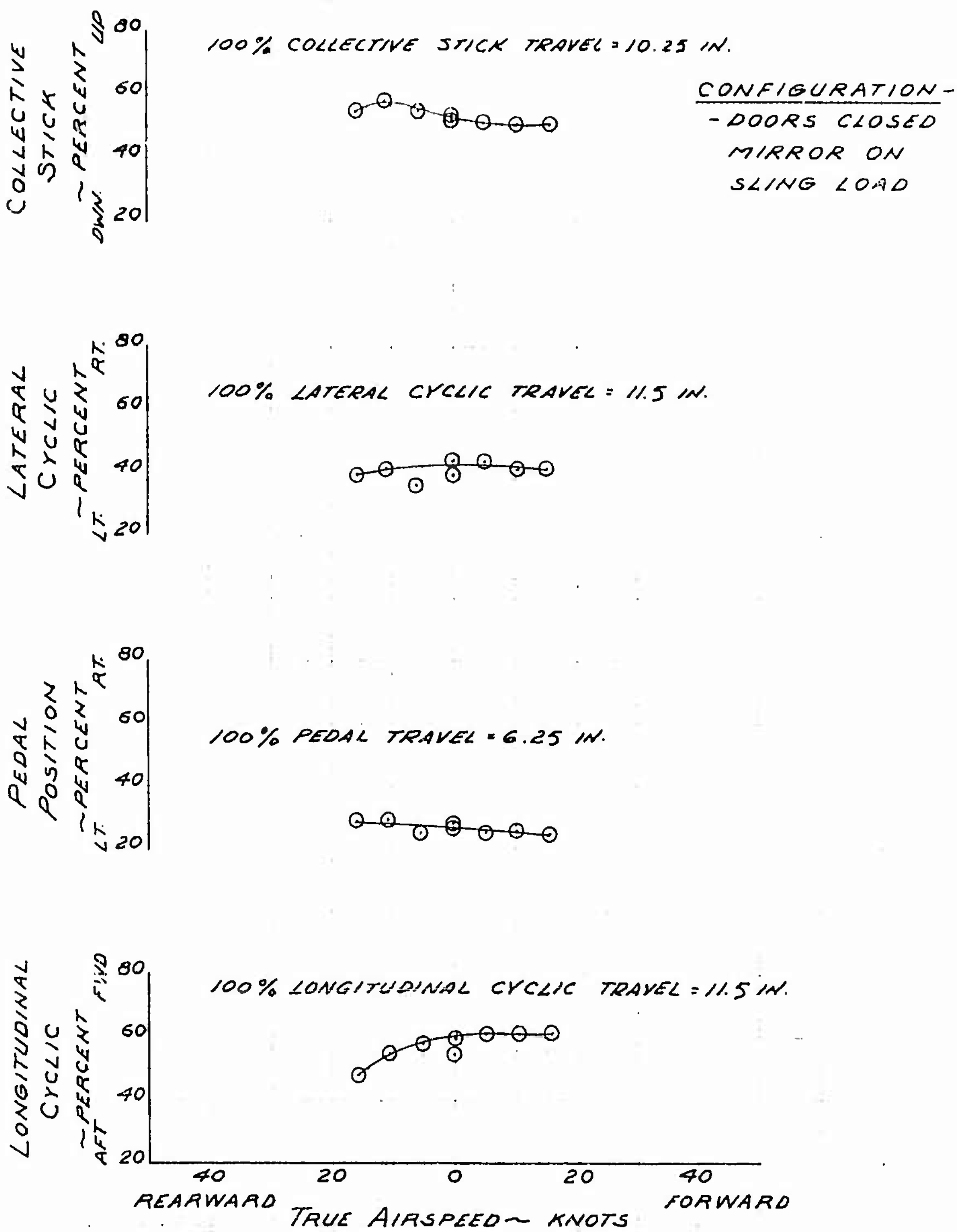

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FIGURE NO. 62

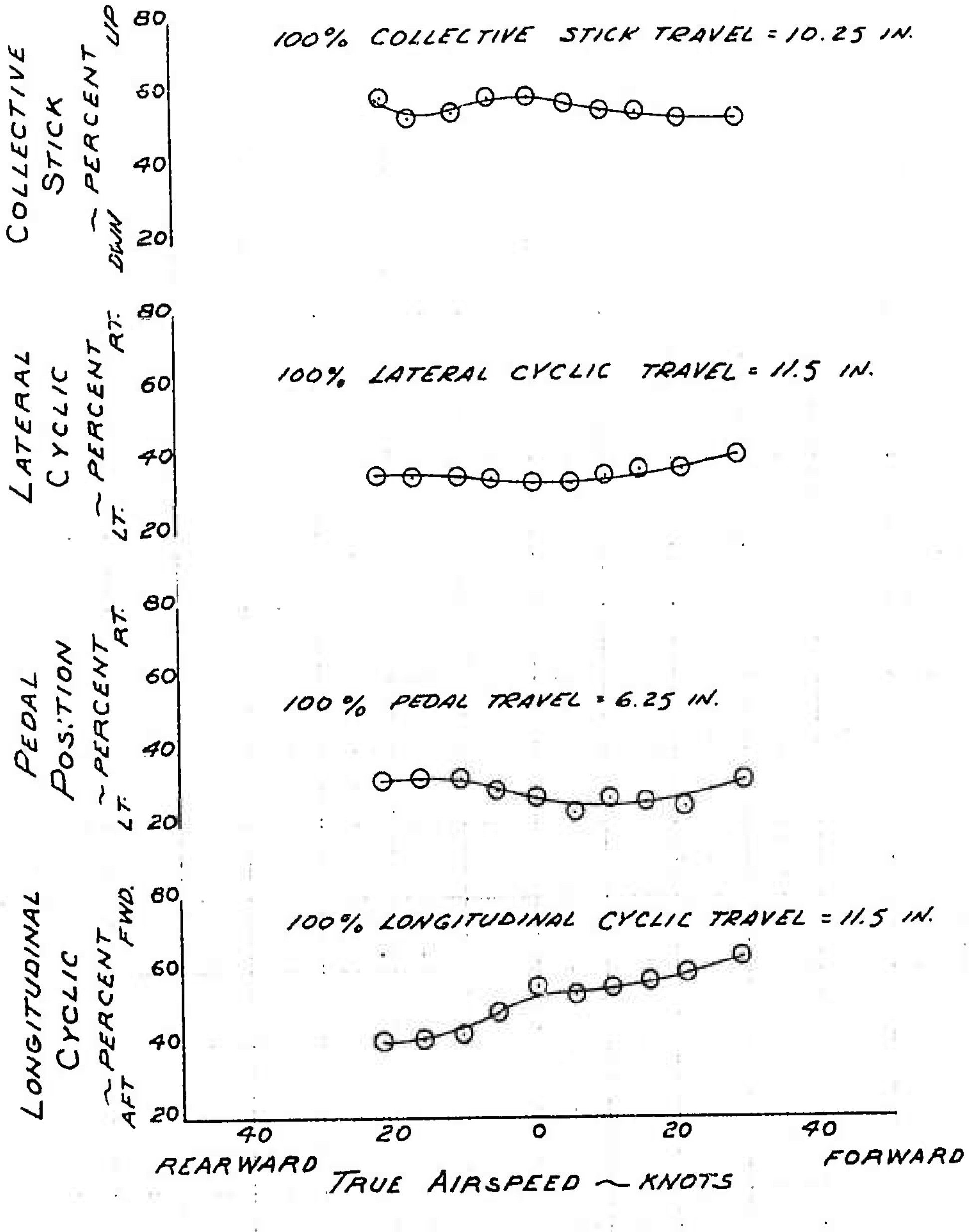
CONTROL POSITIONS IN REARWARD FLIGHT

MODEL 211 S/N N6256N

HUEY TUG

AVG. GROSS WT.	AVG. C.G. STATION	AVG. DENSITY ALT.	ROTOR SPEED
13230 LBS.	131.97 IN	4545 FT.	298 RPM

CONFIGURATION -
- DOORS CLOSED
MIRROR ON
SLING LOAD



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APPENDIX V.
TEST INSTRUMENTATION

The following test instrumentation was used throughout the conduct of the test:

Performance (hand recorded)
- Engine torquemeter
- Sensitive rotor tachometer
- Outside air temperature
- Altimeter
- Calibrated airspeed (nose boom)
- Fuel used
- N_1 tachometer (production)
- Exhaust gas temperature
- Compressor inlet temperature (4 probes)
- Compressor inlet total pressure (4 probes)
- Main and tail rotor shaft torque
- Time

Stability and control (oscillograph recorded)
- Control positions
  - Longitudinal cyclic
  - Directional pedal position
  - Lateral cyclic
  - Collective control
- Rate gyros
  - Pitch
  - Roll
  - Yaw
- Attitude gyros
  - Pitch
  - Roll
- Accelerometers
  - Center of gravity vertical
  - Pilot vertical

Sideslip angle
SCAS actuator positions
Main rotor-flapping angle
Rotor rpm
Engine torque

APPENDIX VI. PILOT'S RATING SCALE

CONTROLLABLE CAPABLE OF BEING CONTROLLED OR MANAGED IN CONTEXT OF MISSION, WITH AVAILABLE PILOT ATTENTION	ACCEPTABLE MAY HAVE DEFICIENCIES WHICH WARRANT IMPROVEMENT, BUT ADEQUATE FOR MISSION. PILOT COMPENSATION, IF REQUIRED TO ACHIEVE ACCEPTABLE PERFORMANCE, IS FEASIBLE.	SATISFACTORY MEETS ALL REQUIREMENTS AND EXPECTATIONS, GOOD ENOUGH WITHOUT IMPROVEMENT. CLEARLY ADEQUATE FOR MISSION.	EXCELLENT, HIGHLY DESIRABLE	A1
			GOOD, PLEASANT, WELL BEHAVED	A2
			FAIR. SOME MILDLY UNPLEASANT CHARACTERISTICS. GOOD ENOUGH FOR MISSION WITHOUT IMPROVEMENT.	A3
		UNSATISFACTORY RELUCTANTLY ACCEPTABLE. DEFICIENCIES WHICH WARRANT IMPROVEMENT. PERFORMANCE ADEQUATE FOR MISSION WITH FEASIBLE PILOT COMPENSATION.	SOME MINOR BUT ANNOYING DEFICIENCIES. IMPROVEMENT IS REQUESTED. EFFECT ON PERFORMANCE IS EASILY COMPENSATED FOR BY PILOT.	A4
			MODERATELY OBJECTIONABLE DEFICIENCIES. IMPROVEMENT IS NEEDED. REASONABLE PERFORMANCE REQUIRES CONSIDERABLE PILOT COMPENSATION.	A5
			VERY OBJECTIONABLE DEFICIENCIES. MAJOR IMPROVEMENTS ARE NEEDED. REQUIRES BEST AVAILABLE PILOT COMPENSATION TO ACHIEVE ACCEPTABLE PERFORMANCE.	A6
	UNACCEPTABLE DEFICIENCIES WHICH REQUIRE MANDATORY IMPROVEMENT. INADEQUATE PERFORMANCE FOR MISSION EVEN WITH MAXIMUM FEASIBLE PILOT COMPENSATION.		MAJOR DEFICIENCIES WHICH REQUIRE MANDATORY IMPROVEMENT FOR ACCEPTANCE. CONTROLLABLE. PERFORMANCE INADEQUATE FOR MISSION, OR PILOT COMPENSATION REQUIRED FOR MINIMUM ACCEPTABLE PERFORMANCE IN MISSION IS TOO HIGH.	U7
			CONTROLLABLE WITH DIFFICULTY. REQUIRES SUBSTANTIAL PILOT SKILL AND ATTENTION TO RETAIN CONTROL AND CONTINUE MISSION.	U8
			MARGINALLY CONTROLLABLE IN MISSION. REQUIRES MAXIMUM AVAILABLE PILOT SKILL AND ATTENTION TO RETAIN CONTROL.	U9
UNCONTROLLABLE CONTROL WILL BE LOST DURING SOME PORTION OF MISSION.			UNCONTROLLABLE IN MISSION.	10

APPENDIX VII. CONTROL MOTION

Amount of control movement with percent travel of all flight controls is as follows:

Longitudinal	1% = 0.115 inches
Lateral	1% = 0.115 inches
Directional	1% = 0.0625 inches
Collective	1% = 0.1025 inches

APPENDIX VIII. DISTRIBUTION

Agency	Test Plans	Equipment Failure Reports	Interim Reports	Final Reports
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Theodore K. Wright, LTC, ARTY, US Army, Project Officer
Ivar W. Rundgren, MAJ, TC, US Army, Project Pilot
John I. Nagata, Project Engineer

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13. ABSTRACT

The Army Preliminary Evaluation (APE) of the Bell Model 211 prototype helicopter (Hueytug) was conducted at the Bell Helicopter Test Facility, Arlington, Texas, Edwards AFB, California, and Bishop, California, from 19 October through 7 November 1968. Flying qualities, performance, and mission suitability were evaluated to determine aircraft capabilities to carry six thousand pound sling loads at a takeoff gross weight of 14,000 pounds. Primary emphasis was directed toward the artillery mission of displacing a 105mm howitzer M101A1 with 10 rounds of ammunition and 3 cannoneers. The helicopter had eight deficiencies which require mandatory corrections. Two of these are major design deficiencies that may require extensive engineering redesign. They are the directional oscillations in the 30 to 60 KIAS airspeed range, especially prevalent during heavy sling load missions; and lack of sufficient directional control margin during high gross weight (14,000 pounds) and high density altitude (above 4000 feet) conditions. The remaining six deficiencies are ineffective force trim feature at high airspeeds, excessive forward position of longitudinal control at high airspeeds, poor static engine droop compensation, tail rotor drive train torque limitations, lack of an engine power torque limiter and lack of a standby generator for IFR flight. There are seven shortcomings the corrections of which are desirable and should be accomplished as soon as possible. The prototype model 211 could marginally perform the 14,000 pound gross weight mission at sea level. At 4000 feet density altitude the marginal tail rotor control and transmission and drive train torque limitations prevented the helicopter from satisfactorily accomplishing the mission. Correction of the deficiencies discovered during this APE coupled with the 200 horsepower increase in drive train torque limits of the design proposal should result in a superior performing helicopter. Correction of the deficiencies should be accomplished prior to a production contract.

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Bell Model 211 Prototype Helicopter						
Army Preliminary Evaluation						
Flying Qualities						
Performance						
Mission Suitability						

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